



IMPERIAL AGRICULTURAL  
RESEARCH INSTITUTE, NEW DELHI.

MGIPC—S4—111-1-93—22-8-45—5 000.





*THE annual volumes of Papers of the Michigan Academy of Science, Arts, and Letters are issued under the joint direction of the Council of the Academy and of the University of Michigan Press. The editor for the Academy is Henry van der Schalie; for the University, Eugene S. McCartney.*

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MICHIGAN ACADEMY OF SCIENCE  
ARTS AND LETTERS

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VOLUME XXX (1944)

CONTAINING PAPERS SUBMITTED AT THE ANNUAL  
MEETING IN 1944

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VOLUME XXX IS AVAILABLE IN FOUR PARTS:

PART I: BOTANY AND FORESTRY

PART II: ZOOLOGY

PART III: GEOGRAPHY AND GEOLOGY

PART IV: GENERAL SECTION

ANTHROPOLOGY, ECONOMICS

LANGUAGE AND LITERATURE

MEDICAL SCIENCE, SOCIOLOGY



PAPERS OF THE  
MICHIGAN ACADEMY OF SCIENCE  
ARTS AND LETTERS

EDITORS

EUGENE S. McCARTNEY  
HENRY VAN DER SCHALIE

VOLUME XXX (1944)

"Pusilla res mundus est nisi in illo  
quod quaerat omnis mundus habeat."

— SENECA, *Naturales Quaestiones*

ANN ARBOR: THE UNIVERSITY OF MICHIGAN PRESS  
LONDON: HUMPHREY MILFORD, OXFORD UNIVERSITY PRESS

1945

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Set up and printed,  
August, 1945  
Published September, 1945

PRINTED IN THE UNITED STATES OF AMERICA  
BY THE PLIMPTON PRESS • NORWOOD • MASS.

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# BOTANY





# SILICIFIED PLANT REMAINS FROM THE MESOZOIC AND TERTIARY OF WESTERN NORTH AMERICA

## I. FERNS

CHESTER A. ARNOLD

### INTRODUCTION

**T**HE silicified plant remains of the Mesozoic and Tertiary of western North America have offered many opportunities for paleobotanical research, which often have been neglected. Although the scarcity of properly trained investigators has been partly responsible for this neglect, a more important element has been the prevailing notion that the material consists only of the secondary wood of gymnosperms and dicotyledons which is so difficult to identify that the effort expended would not be justified by the results obtained. Another deterrent, and one of a practical nature, is that most of these woods are as hard as quartz, and the preparation of thin sections suitable for study requires labor, patience, persistence, and a certain minimum of skill. In addition, properly constructed cutting equipment must be available when any amount of material is to be studied. Cellulose peels, which have been widely used within recent years for coal-ball petrifications, cannot always be successfully made from silicified plants because the etching process often destroys the tissue structure. It is only in woods, usually those with a very dark color, in which the cell walls have retained much of their original organic content, that the intercellular and intracellular silica can be dissolved away without the structure suffering severe damage. The brighter and more brilliantly colored woods are usually without much cell structure, and they cannot often be successfully studied even in ground preparations.

Regardless of the technical difficulties that may be encountered in studying silicified plant remains, some spectacular results have been achieved, as is shown by the investigations of Lester F. Ward and George R. Wieland on the cycadeoids of the Black Hills and

Freezeout Mountain regions of South Dakota and Wyoming. In this group of extinct plants the vegetative and reproductive structures have been analyzed to a degree of completeness approaching that of Recent species. Then there are other instances, on a much smaller scale, of noteworthy achievements in the study of silicified plants from the western states, but no groups other than the cycadeoids have been subjected to thoroughgoing and systematic investigations. Leaf impressions, on the other hand, have been ardently collected in prodigious quantities for nearly a century. Important results have been obtained, and the literature relating to them amounts to volumes. Although they require no elaborate preparations for study, as do petrifications, their correct interpretation is often a subtle matter which may tax the ingenuity of even the most experienced investigators.

Plant morphologists showed us long ago that relationships are sometimes revealed through internal structure when external form fails. This is especially true in paleobotany, for the whole plant with all parts attached is seldom found. An outstanding example of this principle was the discovery during the latter part of the last century of petrified stems in the Coal Measures which showed a combination of filicinean and cycadean characteristics, but which occurred among foliage ordinarily regarded as belonging to ferns. The conclusion based upon the anatomical evidence was that here exists a member of an extinct group occupying intermediate status, a supposition later substantiated when seeds were found attached to the foliage. Thus, the greater the evidence that can be brought to bear upon any particular problem, the more conclusive the results will be. Anatomical evidence has been used more extensively for Paleozoic plants than for later ones, but it is a useful adjunct even in the classification of Recent species.

The majority of the silicified plants of western North America are woody dicotyledons, followed in decreasing order by conifers, monocotyledons (principally palms), cycadeoids, and ferns. As has been stated, only the cycadeoids have been comprehensively studied. The present account is concerned with two new genera and five new species of ferns which range from the early or middle Cretaceous into the Eocene. The assembling of the material was made possible only through the cooperation of several collectors, most of whom are residents of the regions from which it came. Those who have

furnished or lent specimens for study are Mr. V. D. Hill, Mr. J. W. Berry, Mrs. Ethel Smith, Mr. H. Timmel, Mr. and Mrs. F. W. Dennler, Mr. George Futa, Mr. Fred Salfisberg, and the late Mr. Louis Wessel.

## I. AN *OSMUNDITES* FROM CENTRAL OREGON

To date only two structurally preserved stems of *Osmundites* have been reported from North America. *O. skidegalensis* was described by Penhallow (16) from the Lower Cretaceous of the Queen Charlotte Islands in 1902, and in 1941 Daugherty (10) described *O. walkeri* from the Triassic of Arizona. The discovery of a third specimen in the Tertiary of Oregon is of special interest in that it supplies evidence, in addition to that furnished by foliage compressions, of the westward extension during that period of osmundaceous ferns which at present in North America are restricted to the eastern part of the continent.

The specimen, a transverse slice about 3 cm. in thickness of a silicified stem approximately 6 cm. in diameter, was noticed by the author among a collection of agates owned by Mr. V. D. Hill, of Salem, Oregon. Mr. Hill very kindly submitted a portion of the specimen for study. The stem was originally found by other persons, who refused to divulge the exact source, but inquiry has revealed that it came from within ten miles of Post, Oregon. For this reason it seems improbable that the specimen could have come from any formation other than Tertiary. Post is located on the Crooked River slightly to the southwest of the center of the state, and the formations in that region range from early Tertiary to Miocene. The oldest formation in the vicinity of Post is the Clarno, which is believed to be either Eocene or early Oligocene. The Clarno is overlain unconformably by the John Day series. The lower portion of the John Day series contains the Bridge Creek plant-bearing shales, which are believed to be of upper Oligocene age. Above the John Day is the Columbia lava, followed by the Mascall formation, which belongs to the Miocene. No Cretaceous or older beds have been definitely recognized nearer than Paulina, which is about thirty miles from Post.

Plants have been found along the Crooked River in the Clarno and Bridge Creek shales, and the largest flora was secured from the

latter at Gray's Ranch, eleven miles east of Post (Chaney, 8). These plant occurrences offer no proof, however, that the *Osmundites* stem came from the Clarno or the Bridge Creek beds, because silicified plant material is common in the Tertiary sediments throughout the whole area. Nevertheless, the presumptive evidence is that it is not older than Eocene or younger than Miocene.

The specimen is highly agatized, and although its tissues are very poorly preserved, its generic identity is evident even upon casual observation. In the center are two vascular cylinders which diverge slightly from one transverse surface of the specimen to the other. This shows that the cut was made just above a fork in the stem (Pl. I, Fig. 1). Both axes are enclosed by a thick mantle of adhering leaf bases which in osmundaceous ferns, both living and fossil, makes up the bulk of the trunks. The leaf bases are oval in cross section, with a C-shaped vascular strand in which the concavity is turned toward the center (Pl. I, Fig. 2). At one side of the specimen the outermost leaf bases are oriented in the opposite direction, which shows that the stem had forked a second time at a lower level (Pl. I, Fig. 1, at left). Since branching is infrequent in the living species of *Osmunda*, it is remarkable to find evidence of two rather close dichotomies in a fossil specimen.

Each vascular cylinder is about 6 mm. in diameter. Tissue preservation is very poor, and about all that can be said concerning the structure is that the xylem appears to consist of sixteen or more separate strands around a central pith. The distribution of the phloem and the endodermis, features essential in comparing material with Recent species, is undeterminable. Around the almost clear silica-filled vascular region is the brownish cortical layer through which several leaf traces pass. In the cortex the xylem of the trace is a small reniform mass of tracheids (one of the few places where cells can be seen) with the indentation innermost. As the trace emerges from the cortex the indentation becomes deeper and the petiole base is surrounded by a layer of dark-brown supporting tissue. Those petioles to the outside of the mantle become increasingly larger until they reach a maximum tangential diameter of about 7 mm. Passing outwardly in a more or less horizontal direction among the petiole bases are numerous adventitious roots (Pl. I, Fig. 2).

The geological history of the Osmundaceae is better known than that of most Recent fern families. Structurally preserved stems

known as *Zalesskya* and *Thamnopteris*, which are undoubtedly members of the Osmundaceae, occur in the Permian. There are no undisputed records of osmundaceous ferns in older Paleozoic rocks, although the family may be foreshadowed by fructifications and stems of the Lower and Upper Carboniferous usually assigned to the Botryopteridaceae. Stems definitely referable to *Osmundites* are known from the Triassic rocks (Kidston and Gwynne-Vaughan, 13; Daugherty, 10), but the genus appears to have reached the height of its development during the Jurassic.

*Osmunda* (*Osmundites*) is rare in the Tertiary of North America, probably having disappeared entirely from the western part of the continent during the middle or the latter part of that period. It is rarely found in rocks younger than Eocene, and is not common even there. However, it is possible that from time to time the genus has been overlooked because of the ease with which the barren foliage may be mistaken for that of other genera. The frond fragments described by C. C. Hall (in Chaney, 8, p. 100) as *Pteris silvicola*, from the Gray Ranch along the Crooked River, are quite similar to the normal frond parts of the eastern *Osmunda cinnamomea*, and could, it seems, be assigned to this species as readily as to the bracken fern. The bracken, of course, is a member of the coastal redwood association with which the Bridge Creek flora has much in common, but the Bridge Creek flora also contains an eastern element of eight species to which *Osmunda* would be a not unexpected addition.

On account of poor preservation of the tissues it is impossible to compare the specimen in detail with living or fossil species other than to note a general similarity with the cinnamon fern *Osmunda cinnamomea*. However, in the absence of material showing the presence of internal phloem in the vicinity of the branches its identity with this species cannot be more than merely suggested. It is given the name *Osmundites oregonensis* in order that it may be placed on record and that future reference to it may be facilitated. It is hoped that subsequent discoveries will reveal the structure more adequately.

*Osmundites oregonensis*, sp. nov. — Dichotomously branched stems surrounded by a thick mantle of leaf bases and adventitious roots. Xylem cylinder of 16–20 separate strands surrounding a pith. Outermost petioles of mantle oval, about 7 mm. broad, and each containing a C-shaped xylem strand.

Holotype No. 23389, Univ. Mich. Coll.

## II. A FERN PETIOLE FROM THE GREEN RIVER FORMATION

The following description is based upon some silicified petiole fragments which, when first examined, were thought to belong to a monocotyledon, but the lack of vessels, combined with the distribution of the bundles, seems to furnish indisputable evidence that they represent a fern. Cycadaceous affinities are excluded by the absence of centripetal wood in the bundles and by the lack of mucilage canals. The specimens came from the Eocene Green River formation and were collected in the so-called Eden Valley petrified forest, which is located about twenty-six miles east of Farson, Sweetwater County, Wyoming, and about six miles east of the Hay Ranch. This locality has long been famous for its delicately colored agatized limbs, of which large quantities have been removed by gem-stone collectors. It also yields palm trunks and other plant remains. No systematic study, however, of the petrifications from this place has been made.

The petioles, which range from 12 to 22 mm. in diameter, are rounded or slightly angular, with a broad adaxial furrow (Pl. II, Fig. 1). The outer part consists of a layer of sclerenchyma made up of small, compact, thick-walled fibers, and the interior contains collateral bundles distributed throughout a ground tissue of thin-walled cells and large intercellular spaces (Pl. II, Fig. 2). Each bundle is surrounded by a sheath of fibers several cells in extent, and the fibrous sheaths of the outermost layer of bundles are connected with the external sclerenchyma by a narrow isthmus of fibers. In most bundles the phloem and the accompanying parenchyma have disintegrated and thus have left the xylem somewhat displaced from its original position within the large oval or circular bundle cavity, but the orientation of the xylem and the phloem is usually evident from the position of the protoxylem. Longitudinal sections show that the xylem consists of scalariform tracheids. In some of the bundles there is evidence of a thin-walled endodermis inside the sclerenchymatous sheath.

The bundles are distributed according to a definite plan, although partial disintegration of the tissues in parts of all sections that have been examined interfered with the determination of the arrangement. Moreover, the arrangement is not identical in any two specimens, although there is evidence that the differences are merely

modifications of one type. In the large leaf stalks, where there are two hundred or more bundles, the arrangement is more complex than that in the smaller ones with fewer bundles.

Extending across the bottom of the petiole section and up both sides is the peripheral bundle layer, in which the phloem is toward the outside and the xylem to the inside (Fig. 1A, *d*). At its upper

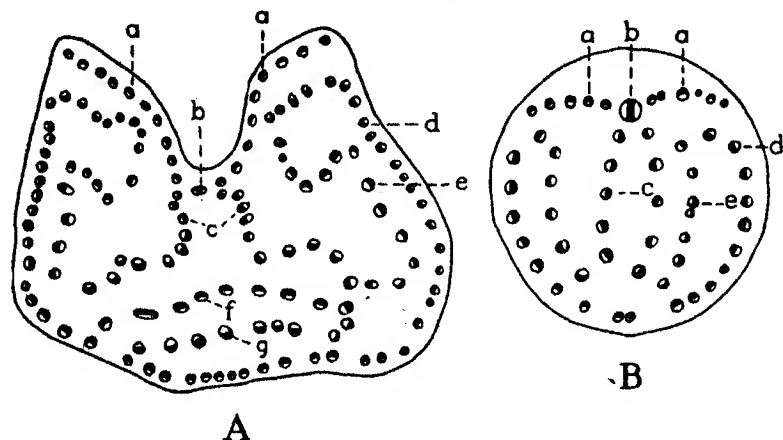


FIG. 1. Diagrams, A and B, showing the bundle distribution in *Eorhachis lomarioides* and *Blechnum zamioides*, respectively. The lower-case letters identify similar structures in each: *a*, adaxial segments with outwardly directed xylem; *b*, double bundle; *c*, internal bundle bands flanking median line of petiole; *d*, peripheral bundle band; *e*, inward extension; *f, g*, internal bundle bands. A, tracing from original; B, after Thomae

extremities the ends of the bundle bands turn inward, and they extend downward as bands internal to the outer layer with the phloem and xylem oriented in the opposite direction (Fig. 1A, *e*). Extending across the top of the petiole section is another band (Fig. 1A, *a*) of bundles in which the xylem is toward the outside. At the mid-point of this band (Fig. 1A, *b*) there is a double bundle from which two bands of bundles extend deep into the interior of the petiole (Fig. 1A, *c*) on opposite sides of the median line. The arrangement from here on is slightly uncertain, but these median bands appear ultimately, after undergoing a few minor folds, to connect with the infolds of the lateral peripheral bands just described.

Among living ferns *Blechnum zamioides* shows a bundle pattern



in the petiole that is apparently a modification of the same arrangement (Thomae, 24, Pl. VI, Fig. 2a). The Recent and the fossil petioles agree in having a transverse adaxial bundle band in which the xylem is turned toward the outside. Then from the double median bundle (Fig. 1B, b) two bands extend into the interior. Thomae interprets the bundle complex in *B. zamiioides* as having been derived from two strands arranged in an arc, but with the sides infolded in such a manner as to resemble two figure 5's with one turned to face the other (Fig. 2). The halves of the transverse

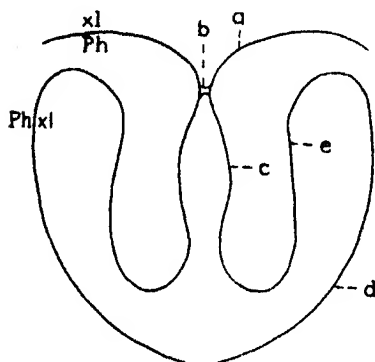


FIG. 2. Diagram showing the form of the bundle bands in *Blechnum zamiioides* as described by Thomae. xl, xylem; ph, phloem. Other lettering as in Figures 1A and 1B

adaxial band consist of two side segments connected at the median line of the petiole by a double bundle (Fig. 1B, b). These are continuous with the deeply infolded bands which loop downward and then upward in the interior and finally extend along the periphery, terminating at the abaxial side of the petiole at the median line (Fig. 1B, c, d, e). The pattern in the fossil form is believed to be similar to this in several respects at least, although it may be somewhat modified. At the bottom of the section and extending crosswise to the median

vertical line there are two bands arranged in a flat transverse oval which represent either additional bands or branches from the two lateral ones (Fig. 1A, f, g). The former of these alternatives seems more probable.

The resemblances noted between the fossil petiole and that of *Blechnum zamiioides* would suggest relationship with the Aspleniaceae. It should be mentioned, however, that very little information is available concerning *B. zamiioides*. It is not listed by Christensen in his *Index Filicum*, and Thomae states that the structure deviates considerably from that of other and more typical members of the genus. Therefore, since the Recent fern which most closely resembles the fossil is apparently atypical of the genus to which it belongs, and is little known, the exact relationships of the fossil are dubious, and

the suggested affinity with the Aspleniaceae rests only upon such interpretations of the bundle distribution as are possible from the material at hand and the resemblances to Thomaë's figure of *B. zamioïdes*. Resemblances of a still remoter nature may also exist among certain members of the Polypodiaceae, and the structure of the ground tissue also compares with that of *Ceratopteris* of the Parkeriaceae. There is little or nothing to invite comparison with the Cyatheaceae or the Marattiaceae. In the former the numerous bundles of the petiole are arranged in an upper and a lower series, with the phloem of the upper series to the outside, and in those of the Marattiaceae that may be compared (as in *Angiopteris*) there is an evident cyclic arrangement.

*Blechnum zamioïdes* belongs to the subgenus *Lomaria*, which is distributed at present throughout the East Indies, Australasia, and Madagascar. No members of the genus *Blechnum* have so far been reported from the Green River formation, and the only representative in it of the Aspleniaceae is *Asplenium coligniticum*. In fact, only seven ferns have been identified from the entire Green River formation (Brown, 6). Considering the warm-temperate nature of the Green River flora it is only to be expected that it will ultimately be found to contain additional fern types, especially those which at present do not exist so far north.

The fern represented here evidently was a water plant or one which was rooted in very wet soil. Apparently it bore fairly large fronds, as is indicated by the amount of sclerenchyma present, and in habit it might have resembled some of the Recent species of *Blechnum* which are small tree ferns. In view of the uncertainties concerning relationships it seems advisable not to refer this plant to any genus of Recent ferns, but to follow the established practice in paleobotany of creating form genera for such remains. The generic epithet *Eorhachis* is therefore proposed for this ancient fern petiole of uncertain affinity.

***Eorhachis lomarioides*, gen. et sp. nov.** — Fernlike petiole, rounded or angular in cross section, with a broad adaxial groove or concavity; 10–22 or more mm. in diameter; bundles numerous, collateral, surrounded by sclerenchymatous sheath, and arranged in two or more series, which are probably derived from solid strands arranged in an arc; peripheral bundles normally oriented, those of adaxial band reversed; supported externally by a thin layer of sclerenchyma;

ground tissue with numerous intercellular spaces suggestive of an aquatic habit.

Holotype No. 23390; paratypes Nos. 23391-23395, Univ. Mich. Coll.

### III. A TREE FERN FROM SOUTHERN TEXAS

In 1934 Miss Elzada Clover and Mrs. Eleanor Cook Beard secured several silicified tree-fern specimens from a locality about ten miles north of Roma, Starr County, Texas. The exact place is not on record, but the probabilities are that the stems came from the Fayette formation of the lower Upper Eocene. There is also a chance that they came from the underlying Yegua formation (also known as the Cockfield), which has yielded plant remains, including silicified palm trunks (Berry, 3; Sellards and others, 18), but in his account of the Cenozoic geology of the lower Rio Grande valley Trowbridge (25) makes numerous references to silicified wood in the basal part of the Fayette. According to the geological map accompanying Trowbridge's paper, a considerable area extending to within a short distance north of Roma is covered by the Fayette formation, with the Yegua outcropping a short distance to the west. The Fayette lies conformably upon the Yegua, and Berry (3) believes that part of what is commonly regarded as Yegua may belong to the overlying formation. So even though the exact stratigraphic position of the rocks from which the fern material came may be in doubt, it is either upper Middle Eocene or lower Upper Eocene, probably the latter.

The specimens are of small trunks ranging from 5 to 10 or more cm. in diameter. The surface is uneven because of the projecting leaf bases, which form a mantle over the stem (Pl. III, Fig. 1). The leaves did not become detached by any normal shedding process, and they remained in place until removed by decay or abrasion. The leaf bases are arranged in a close spiral and project from the stem at an angle of about 45 degrees. In a cross section about twelve leaf bases may be seen in various stages of departure (Pl. IV, Fig. 1; Text Fig. 3). The higher ones show only as outward bulges of the solenostele, whereas the lower ones may be almost detached. The free portions of the petioles are 2 cm. or less in diameter.

Covering the surface of the stem between the leaf bases is a ramentum of flattened, overlapping multicellular hairs which vary from 1 to 2 mm. in width and up to 1 cm. in length. In cross section

they are spindle-shaped and eight to twelve cells thick along the middle portion (Pl. VI, Fig. 3). The light-colored interior of the hair is surrounded by a darker layer three or more cells in depth. The cell walls throughout the hair are thick, which probably made them stiff and bristle-like. The significance of these hairs with respect to the relationships of the plant is discussed later.

#### ANATOMY

The stems are thoroughly silicified, and in most specimens only the gross anatomical features are visible. In only a few is preservation such that minute details can be satisfactorily studied. Unweathered broken or cut surfaces have a brownish color, which is often quite patchy and uneven, with the result that it is difficult to obtain good photographs of some of the structures. It was impossible to prepare satisfactory cellulose peels, but petrotome sections of some of the specimens show details well if ground sufficiently thin. Smoothly ground surfaces covered with a thin solution of isobutyl methacrylate in xylol and allowed to dry were sufficient in nearly all instances to show everything except the most minute structural details. Such preparations were especially useful in examining large surfaces, and with reflected light it was even possible to see considerable detail under the low power of the compound microscope. They could be very satisfactorily studied with the Greenough-type binocular microscope.

In cross section the outline of the trunks is irregular because of the unevenly projecting but closely spaced leaf bases (Pl. IV, Fig. 2). Very little is known of the epidermis or the thin cortical layer other than the mere fact that they are present beneath the ramentum. The surface covered by the ramentum is very small because of the size and close proximity of the leaf bases, and as a result of the leaf-base mantle and the ramentum no part of the stem surface was exposed.

Only a few millimeters inside the surface to which the mantle and ramentum are attached is a deeply fluted irregular solenostele, the continuity of which is rarely if at all interrupted by leaf gaps (Pl. IV, Fig. 1; Text Fig. 3). The xylem of the solenostele shows on the smooth polished surfaces as a light band 1 mm. or less in thickness, but flanking it on both sides is a sclerenchymatous layer of about equal thickness (Pl. VI, Fig. 2). The thin phloem which

originally accompanied the xylem on both sides is not preserved, and the space is filled with disorganized material. The xylem consists of angular scalariform tracheids which, however, are seldom cut crosswise in a transverse section. Instead of extending vertically,



FIG. 3. Cross section at two levels showing the change in configuration of the solenostele within a distance of 6 mm. Comparable structures are shown by letters *a-f*. It will be noted that in B the outward extension of the solenostele shown at *a* in A has become completely detached and the leaf gap has closed within the short distance separating the two sections. The outlines of the stem and the meristele are as accurate as it is possible to trace them. The number and distribution of the bundles in the leaf bases are only approximate, and the medullary bundles are omitted

they often lie transversely or at an angle, or, as may be seen at numerous places, they appear much contorted and follow an irregular course. This irregularity, however, is due in part to the course of the xylem itself. Lengthwise sections show that the vertical course of the xylem is irregular, with frequent bends that often reverse the direction of the layer for short distances. Consequently, sections cut transversely to the axis never pass through all parts of the xylem at right angles to its up-and-down direction.

Owing to the general state of preservation structural details of the xylem are difficult to observe, but there is no reason to believe that it differs markedly from ordinary fern xylem. It consists mostly

of scalariform tracheids with but little intermixed parenchyma. The protoxylem has not been identified (Pl. VI, Fig. 4).

The pith, or that part enclosed by the solenostele, contains numerous medullary bundles, often so closely packed that little or no space remains for typical pith tissue. No attempt was made to form even an approximate idea of the number of these medullary bundles, but they can probably be counted by hundreds. Only a very few instances have been observed of a direct connection between the medullary bundles and the solenostele, so that the relation between these two parts of the stelar system is unknown. Those toward the center of the pith tend, however, to be more irregular in size and shape than those near the periphery and to branch more frequently. Also, they do not all follow a vertical course, but many of them extend cross-wise or bend in various ways. The outermost ones are more rounded in cross section and follow a more vertical direction. This slight difference in bundle structure in the inner and outer parts of the pith is suggestive of a modified polycyclic condition, although there is no strong evidence to support this interpretation. It does not seem likely, however, that such an elaborate system of medullary bundles as is seen here is related entirely to the solenostele. Numerous medullary bundles pass outward through the foliar portholes from the pith region into the petioles, each receiving nearly a hundred strands (Pl. V, Fig. 1). At the petiole base these strands are embraced within the hollow of the gutter-like trace, and farther out they are still partly surrounded by the separate strands into which the trace becomes divided. They remain readily distinguishable from the trace strands by their smaller size.

The medullary bundles are approximately 0.5 mm. in diameter (Pl. VI, Fig. 1). In most of them the xylem is not preserved, and only the thick sclerenchymatous sheath surrounding each one is left.

The continuity of the solenostele and the seeming absence of leaf gaps in the transverse section of the stem is one of its distinctive and most interesting features. It has been possible by means of a series of slices cut transversely to the petioles but oblique to the transverse plane of the stem to follow the course of the vascular supply of the petiole from the points of its inception to the nearly complete leaf stalk (Fig. 4). The petiole bases are too short to show satisfactorily the arrangement of the tissues in the free petiole, but it appears that the trace supply beyond the leaf-base mantle consists

of separate circular or nearly circular bundles concentrically arranged in two or more cycles (Pl. IV, Fig. 2). These bundles, as will be subsequently shown, originate from two sources.

At the point where the vascular supply of the petiole becomes entirely free from the stem the leaf-trace complex contains, along with other strands to be described later, a trough-shaped strand about twice as wide as deep, with inturned upper margins (Fig. 4*e*). The first indication of the formation of this strand from the solenostele is an outward bulge which, when followed upward, elongates rapidly into a slender tonguelike projection (Fig. 3 at *e*). Before it breaks into separate strands it becomes rather long (Fig. 3 at *a*; Pl. V, Fig. 1). It is evident that the passageway from the medullary region into this tonguelike loop is the morphological equivalent of the leaf gap, but since the opening through the solenostele closes at a level no higher than the acropetal margins of the trough, and since the trough at this level has not yet broken into separate strands, no break is visible in the continuity of the solenostele within a transverse section. A solenostelic instead of a meristelic condition results, therefore, from the abrupt closure of the leaf gap above the point of trace departure. The gap, however, is present in a morphological sense, but it passes obliquely from the pith into the leaf base.

The abrupt closure of the leaf gap produces marked changes in the configuration of the solenostele within very short distances. In one instance (as may be seen in comparing Figs. 3*a* and 3*b*) a complete transition from the long tonguelike projection along the abaxial margin of the trace to the point where detachment was complete took place within a vertical distance of 6 mm. Just above the closed gap the solenostele bends rather abruptly inward (as shown in Fig. 3*b* just below the letter *a*, and at two points in the upper and lower parts of Pl. IV, Fig. 2).

In two or more places where it was possible to follow the changes in the outline of the solenostele from the bottom to the top of the gap a short "compensation tongue" was found to join the lateral margins of the solenostele at the point where the gap would be expected to continue above the acropetal margins of the trace strand (Pl. V, Fig. 2; Text Fig. 4*a*). This short downwardly projecting flap of the solenostele appears to be mainly responsible for the closing of the upper part of the gap (Fig. 4*b*), where it would otherwise occur and cause a break in the continuity of the stele in cross section.

Downward, the tongue narrows abruptly, and within a distance of 2 or 3 mm., or at about the median level of the departing trace, it loses itself among the medullary strands (Pl. V, Fig. 1). Before the

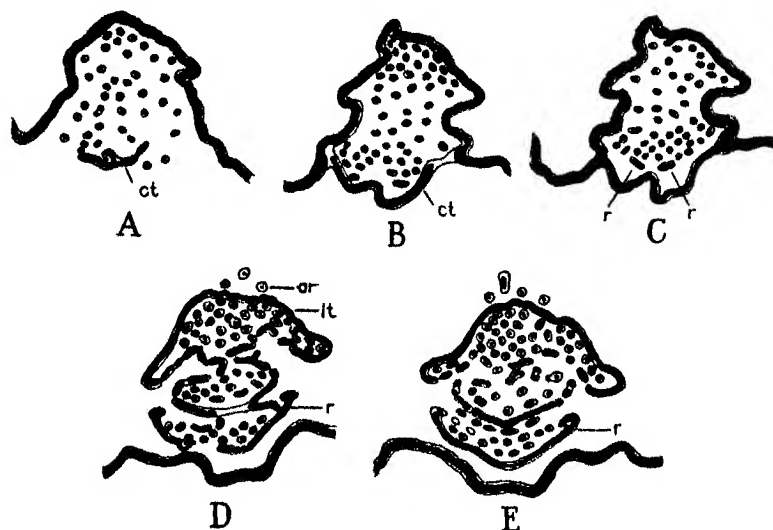


FIG. 4. Camera-lucida tracings of a series of sections showing the development of the leaf trace supply and the closing of the gap by the "compensation tongue," beginning with the lowest: A, section showing the outward bend of the solenostele along the lower abaxial side of the petiole base. The compensation tongue is shown at *ct*, and at B it has broadened until it has closed off the leaf gap. The sclerenchymatous sheath is continuous, but the xylem (in black) has not yet joined the solenostele. The vertical interval between A and B is 4.5 mm. At C the closure of the gap is complete, and two medullary bundles, *r*, have broadened slightly preparatory to forming the "roof." The vertical interval between B and C is 1 mm. At D the trough-shaped leaf-trace strand, *st*, has become completely separated from the solenostele, and three adventitious roots, *ar*, have departed from the outer surface. The roof strands have continued to widen and are partly joined. The vertical interval between C and D is 4 mm. Section E is 1 mm. above D and shows the form of the trough-shaped leaf trace with its inturned margins and the two curved strands of the roof *r*. All  $\times 3$

tongue becomes detached from the solenostele it is easily distinguishable as the inward bend previously mentioned (Pl. V, Figs. 3-4). This compensation tongue seems to be similar to that described by Tansley (23) in *Matonia pectinata* and by Bower (4) in *Thyrsopteris elegans*. In both these ferns the compensation tongue closes the leaf



gap and forms a continuous unbroken solenostele. A continuous solenostele has also been observed in a few other ferns, including *Pteris alata* var. *Karsteniana* and *Dicksonia adiantoides* (Gwynne-Vaughan, 11), but in them the closure is due to a very low leaf gap.

When cross sections of the petiole bases are examined other structures are visible in addition to the trough-shaped strand and the accompanying medullary strands. Lying above the trough and covering the central part like a roof are one or two additional transversely broadened strands which somewhat resemble the lower strand except that it is slightly shorter and less curved. They are inverted with respect to the lower strand (Fig. 4e), with their concave sides downward (uppermost in the figure). At first the origin of these "roof" strands was a mystery because at no place could they be seen attached to or in any way connected with the solenostele, and they are not present over the main trace strand at the level where the compensation tongue closes the gap. However, upon examination of carefully cut oblique sections, it was found that this "roof" originates by the broadening and lateral joining of two or more medullary strands which enter the leaf gap immediately dorsal to the compensation tongue (Fig. 4c-e). The entire leaf-trace supply consists, therefore, of tissue derived from both the solenostele and the medullary bundle system.

Small adventitious roots spring from the abaxial side of the petiole base (Fig. 4d-e).

#### AFFINITIES

The affinities of this plant are believed to be with the Cyatheaceae, the family which includes the majority of the living tree ferns. The most obvious cyatheoid features are the arborescent habit and the general plan of the vascular system. It differs from the more typical members of the family in having an unbroken solenostele. In most species the continuity of the stele is broken at the places where the leaf traces depart by rather wide gaps, and thus separate the vascular ring into meristeles. The difference between these two so-called stelar types is, however, merely a matter of the vertical extent of the leaf gaps and is therefore not a fundamental one, even though the aspect produced by the two in cross section is quite different.

In comparing the fossil fern with living members of the Cyatheaceae the problem is rendered difficult because of our ignorance

of the vascular anatomy of many tree ferns growing at present in the Western Hemisphere. The locality from which the material came is only a few hundred miles north of the present range of tree ferns in Mexico, and it is possible that the living equivalents of the Eocene fern may still thrive among the numerous species of the Cyatheaceae now growing in Mexico or Central America. Until these living ferns are made the subject of a comprehensive anatomical study, it is futile to speculate at length upon this possibility. The most extensive anatomical study of tree ferns made within recent years is by Ogura (14), who gives a detailed account of the eight species found in Japan and Formosa. All the species treated by him have distinct leaf gaps and therefore lack the feature most prominently displayed in our form.

The Cyatheaceae are divided by most authors into three tribes, the Dicksonieae, the Thyrsopterideae, and the Cyatheeae. The fossil apparently does not belong exclusively to any of these tribes, but shows instead characteristics common to all three. Considering first the Dicksonieae, we find in *Cibotium Barometz* a leaf trace which begins as a single gutter-shaped strand with deep lateral folds, but soon breaks into separate bundles. *C. Barometz*, however, has a creeping rhizome, although other members of the genus (as well as the Dicksonieae in general) are upright. Most members of the Dicksonieae lack medullary bundles, although occasionally, as in *Dicksonia rubiginosa*, internal thickenings of the solenostele may become detached and form internal strands in the internodes (Gwynne-Vaughan, 11).

The Thyrsopterideae contain one species, *Thyrsopteris elegans*, which is restricted in its present natural haunts to the island of Juan Fernandez. Probably the foremost point in common between this fern and the fossil is the compensation tongue, already mentioned, which closes the leaf gap above the departing trace, although this structure is present also in *Matonia pectinata* of the Matoniaceae. In *Thyrsopteris* the leaf trace departs from the solenostele as a continuous wavy band, but the sclerenchymatous sheath usually present in the cyatheoids is lacking.

The third tribe, the Cyatheeae, contains three genera, *Alsophila*, *Hemitelia*, and *Cyathea*, all of which are typically meristelic with medullary strands and leaf traces divided into numerous bundles from the place of their origin. In *Alsophila pruinata*, however, the

trace is a horseshoe-shaped band more like that of *Cibotium Barometz*, *Thyrsopteris elegans*, and the Eocene form. Although *A. pruinata* is described as siphonostelic (solenostelic), the condition is the result of long internodes and not of small gaps. The solenostelic condition in *A. pruinata* and the fossil species is, therefore, fundamentally different, and does not furnish a satisfactory basis for comparison.

Concerning the phylogenetic significance of the composite character of this fern, the offhand proposal might be proffered that it is a generalized ancestral type from which the Recent tribes have become segregated. This, however, does not seem as probable as an alternate one that it represents a separate line. In accepting the first hypothesis it becomes necessary to assume that the Recent tribes owe some of their differences to the loss of certain distinctive anatomical features. For example, the Dicksonieae would have lost most of the medullary strand complex and the compensation tongue, the Thyrsopterideae would have retained the latter structure but lost the sclerenchyma, and the Cyatheeae would have lost the compensation tongue and the solid trace strand. It is hardly possible that the medullary strand system, including the compensation tongue, is a primitive feature, so that, with the exception of the troughlike trace strand (which is primitive), the Texas fern probably represents a condition of development about as advanced as any of the living members of the Cyatheaceae. There is no evidence that any of the tribes of the Cyatheaceae originated from ancestors more structurally complex. The original type was probably a simple form not embodying so many seemingly advanced features as are found here.

Although the fossil reveals a combination of tribal characters, it is believed that the sum total of its features indicates a place between the Thyrsopterideae and the Cyatheeae. This view, nevertheless, is subject to future modification since it is based mostly upon the well-developed system of medullary bundles, the sclerenchymatous sheath, the trough-shaped leaf-trace strand, and the compensation tongue. Were it not for the compensation tongue this same set of characters would point toward the Dicksonieae instead of the Thyrsopterideae, because in the latter tribe the sclerenchyma is lacking. So it is a matter of choosing between the compensation tongue and the sclerenchyma as a criterion of affinity, and the view is taken that structures in the vascular system should be selected as having more fundamental phylogenetic meaning than extravascular tissues.

Little may be said by way of comparison with any particular genus of the Cyatheaceae. The three genera *Alsophila*, *Hemitelia*, and *Cyathea* are separated solely on the basis of whether the indusium is absent, partial, or complete, and from the purely anatomical standpoint they are indistinguishable as at present defined.

#### COMPARISONS WITH OTHER FOSSIL FERNS

Because of the widespread practice of comparing with Recent genera compressions of the sterile foliage of fossil ferns in which fructifications or other evidences of affinity are lacking, the early history of the Cyatheaceae is veiled in the same uncertainty that surrounds most of the other fern families. Plants from rocks as ancient as the Culm (equivalent to Lower Carboniferous or Mississippian) have been assigned to the Cyatheaceae, although on evidence that is not satisfactory. Our knowledge of the family properly begins with the late Triassic or Jurassic, in which several frond types bearing cyatheoid fructifications are known. Remains of stems showing either surface features or internal structure resembling the Cyatheaceae appear rather abundantly in the Wealden (basal Lower Cretaceous) of Europe. This shows that the family was more widely distributed in the past than it is now. Up to the present no petrified cyatheoid stems have been reported from North America, and the fossil record of the family consists of a few foliar remains ranging from the Triassic to the Eocene. At no time do the Cyatheaceae ever appear to have been abundant in North America, and it is noteworthy that in the large Wilcox flora of Eocene age they have not been recognized. The Eocene probably marks their last stand north of Mexico, and as the tropical Eocene climates gave way to more temperate conditions the tree ferns retreated southward along with the palms and other tropical plants.

Because soral and sporangial differences are employed much more generally than anatomical characteristics in distinguishing the genera of living ferns, it is frequently impossible to assign fossil stems in these genera, even though the relationships may be obvious. It is therefore often necessary to give special generic names to fossil forms. In the Cyatheaceae the three genera *Alsophila*, *Hemitelia*, and *Cyathea* do not show anatomical differences that correspond to differences in the indusium; hence fossil stems resembling any of these must be placed in separate groups. The literature contains a

number of generic names that have been applied to fossils believed to represent the Cyatheaceae, some of which are *Alsophilina*, *Oncopteris*, *Cyathocaulis*, *Cebotiocaulis*, *Caulopteris*, *Protopteris*, and *Dendropteridium*. *Alsophilina* and *Oncopteris* were originally applied to surface impressions and, therefore, are not suitable for structurally preserved material. *Caulopteris*, also an impression, is used mostly for Carboniferous stems known to possess the internal structure of *Psaronius*. The remaining names, *Cyathocaulis*, *Cebotiocaulis*, *Protopteris*, and *Dendropteridium*, embrace the majority if not all of the known petrified cyatheaceous stems of all ages. *Protopteris*, the first to be proposed (Presl, in Sternberg, 22), refers to stems of tree ferns in which the petiole scar bears a horseshoe-shaped leaf-trace imprint indented at the sides. The leaf bases are spirally arranged about a central axis which contains bandlike vascular bundles, usually in the form of meristeles. Seward (19) provisionally places *Protopteris* in the Cyatheaceae because of its resemblance to *Dicksonia antarctica*. Its several species are confined mainly to the Lower Cretaceous.

*Cyathocaulis* and *Cebotiocaulis* were described by Ogura (15) from the Upper Jurassic and Cretaceous of Japan. Both these genera have large leaf gaps, curved ribbon-like meristeles, and medullary bundles. The names are given apparently in allusion to the similarities of the leaf traces to those of *Cyathea* and *Cebotium*, respectively, but as pointed out by Bancroft (2), they differ from these genera in having medullary roots and inturned meristele margins. *Cebotiocaulis* differs further from *Cebotium* in its medullary bundles. On the other hand, there is little question that they both belong to the Cyatheaceae, and probably to the tribe Cyatheeae. Ogura's genera contain but one species each, *Cyathocaulis nakdongensis* and *Cebotiocaulis Tateiwa*. *Dendropteridium*, also having but one species, *D. cyatheoides*, was described by Bancroft (2) from the Tertiary of East Africa. The specimen described is typically cyatheaceous with medullary bundles, curved meristeles, large leaf gaps, and separate trace strands. *Dendropteridium* is proposed as a form genus "for fossil fern stems of dendroid dimensions, of which, in the absence of associated vegetative and reproductive material, the exact affinities are unknown" (2, p. 251).

Of the four genera of fossil ferns described above (*Protopteris*, *Cyathocaulis*, *Cebotiocaulis*, and *Dendropteridium*) none are acceptable for the fern described here. It may resemble *Protopteris* in several

respects, but this genus is generally used for stems which show the horseshoe-shaped trace strand on the surface, and this feature has been stressed by most authors (for example, by Corda, 9, and Seward, 19, 20). There are differences of opinion, however, regarding the taxonomic value of the shape of the trace scar, but since it always enters into specific descriptions and since some species are based almost entirely upon it, the writer does not deem it advisable to use the name *Protopteris* for specimens in which the trace scar does not show at all on the surface. Moreover, little is known about the anatomy of *Protopteris*. Corda (9), Seward (19, 20), and others have shown that the distribution of the vascular strands is similar to that of the Dicksonieae, but, lacking details, the published figures are insufficient for accurate comparisons. Of course, some degree of relationship between our fern and *Protopteris* is possible in view of the trough-shaped trace strand, which both have in common with the Dicksonieae and the Thyrsopterideae. But, as has been shown, the trace supply of the Texas fern is complicated and consists of strands derived from the medullary system as well as from the solenostele.

There is little in the structure of *Cyathocaulis* that draws comparison other than its general cyatheoid features. It has a system of medullary bundles, but it differs in being meristelic and in having large leaf gaps and separate trace strands. *Cebotiocaulis* is similarly removed from our fern, although the leaf trace does arise as a continuous band, which soon breaks up into separate bundles, and the petiole bases adhere to the stem surface.

As previously explained, the genus *Dendropteridium* was proposed for fossil tree-fern stems the affinities of which are in doubt because of the absence of associated diagnostic vegetative or reproductive parts. Of the four fossil genera under consideration this one is probably the most suitable for the reception of the Texas fern, although it is not an entirely appropriate one. *Dendropteridium* was proposed as a form genus, and apparently was intended for any structurally preserved tree fern that could not be assigned elsewhere. But in our fern the cyatheaceous affinities are hardly to be questioned; hence it should not be placed within a genus which in the future may receive forms not related to the Cyatheaceae. The problem of generic or tribal relationships of our fern arises not only from a lack of associated fronds and fructifications, but also from its peculiar ana-

tomical structure, and to assign it to a form genus such as *Dendropteridium* would be to ignore the value of the anatomical features in its classification. Furthermore, placing it in *Dendropteridium* would be making it congeneric with another species which we know is different; hence the assignment would be entirely arbitrary. The only logical or satisfactory procedure, it seems, is to place the Texas fern within a genus of its own. An alternative would be to amend the genus *Protopteris* (which it resembles more closely than *Protopteridium*) so as to include it, but this should not be done solely on the basis of the published descriptions. It would be necessary to examine some of the original material and to elucidate the anatomical structure more completely.

Since no previously described genus, either living or fossil, seems appropriate for the reception of the Texas tree fern, the name *Cyathodendron* is proposed for it. The diagnosis is as follows.

***Cyathodendron texanum***, gen. et sp. nov. — Stems upright, covered with a mantle of spirally arranged leaf bases and flattened multicellular hairs; vascular system a solenostele accompanied by numerous medullary bundles; all vascular parts surrounded by sclerenchyma; solenostele continuous; leaf gaps small and closed above departing trace by a compensation tongue; leaf-trace supply of numerous strands and derived from solenostele and medullary system; solenostelic trace strand a continuous trough-shaped band with incurved margins, and above this, in inverted position, one or two similar bands formed by fusion of medullary strands passing into the petiole; numerous single medullary strands also present in petiole; adventitious roots arising from abaxial surface of petiole base.

Holotype No. 23405; paratypes Nos. 23406–23407, Univ. Mich. Coll.

#### IV. THE GENUS *TEMPSKYA* CORDA

Recent investigations have shown that the Mesozoic fern genus *Tempskya* is widely distributed in the western part of the United States, especially in the middle and northern Rocky Mountain regions, and further investigations will probably reveal a still wider range. It seems rather strange that this distinctive plant should have remained so long in a state of relative obscurity, because well-preserved specimens have reposed in both privately owned collections

and in public museums for many years. The probable reason that *Tempskya* has only recently received a share of the attention it deserves is that its silicified false stems bear a superficial resemblance to masses of fossil palm roots, and many have been so identified. Preservation is often such that the real nature of the remains is not evident without thin sections, unless one happens to be on the look-out for it. In some localities, notably at Greenhorn, Oregon, the material is attractively colored and is eagerly sought by amateur collectors as an inexpensive gem stone.

The first description of a *Tempskya* from western North America is Seward's account of *T. Knowltoni* (Seward, 21), from Wheatland County, Montana. Nothing more was added to our knowledge of the genus until 1936, when Brown (7) published a short paper in which he set forth its gross distinguishing characters. The macroscopic differences between *Tempskya*, *Palmoxylon*, *Psaronius*, and the woody tissues of the conifers and dicotyledons are briefly explained. In 1937 Read and Brown (17) gave a detailed account of the anatomy of three species of *Tempskya*, two of which were new. Ten western localities are listed, a synopsis is given of the American species, and the taxonomic relationships and stratigraphic range are discussed. They conclude that the genus ranges throughout the Cretaceous, but that in western North America it appears to be restricted to the Colorado group, which is approximately mid-Cretaceous. The most recent contribution is a short paper by Andrews (1), in which references are made to occurrences of *Tempskya* in western Wyoming and adjacent Utah.

Several specimens of *Tempskya* have lately been added to the fossil plant collection of the Museum of Paleontology of the University of Michigan. Most of the material is from new localities in Montana and Wyoming, although some portions of false stems have been secured from "Locality 11" of Read and Brown (17, p. 125) at Greenhorn, Oregon. They merely mention this material because it was received by them too late to be described in their report.

The essential gross and microscopic characters of *Tempskya* have been described by previous authors, so that they need not be repeated here. The aim of the present account is to place on record two new localities for the occurrence of the genus and to describe two additional species. The author is convinced that the species of *Tempskya* cannot be identified from macroscopic characters alone,



and that microscopic examination is necessary. Accurate identification is therefore contingent upon satisfactory preservation, and for the more poorly preserved material it may become necessary to establish "form species" based upon the grosser aspects.

***Tempskya Wessellii*, sp. nov.** — This species is named in recognition of the late Mr. Louis Wessel, of Great Falls, Montana, who furnished the specimen that is here designated the holotype. According to information furnished by him, it came from the Kootenai formation of the "bad lands" northwest of Great Falls. In this region, however, the Kootenai is overlain by the Colorado group, and since elsewhere in western North America *Tempskya* is known only from the Colorado group, it is possible that this material had weathered out of the higher beds. Mr. Wessel stated explicitly, however, that the material is from the Kootenai, and that it was all found within a vertical interval of about three hundred feet.

To this species is assigned the jasperized material of *Tempskya* from the placer outwash at Greenhorn, Oregon (Pl. VII, Figs. 1-2). Although more abundant than the material from Great Falls, it is less well preserved, so that it is considered advisable to designate as the holotype the specimen showing the best tissue preservation. The following diagnosis is based upon the holotype.

False stems radially symmetrical; individual stems 4-5 mm. in diameter, internodes long, usually showing only one leaf trace in a transverse section; cortex distinctly three-layered; outer layer of thin-walled slightly flattened cells with dark contents, constituting about one fourth of the cortical zone; middle layer slightly thicker, fibrous; inner layer about equal in extent to the middle layer, cells thin-walled, oval, with dark contents and often showing an imperfect radial alignment, the layer containing on the outside a continuous band and on the inside a discontinuous band of stone cells; outer endodermis present; pericycle and phloem thin (seldom preserved); xylem with considerable interspersed parenchyma; inner endodermis present; pith sclerenchymatous in center, outer parenchyma layer thin.

Holotype No. 23399; paratypes Nos. 23398, 23401, Univ. Mich. Coll.

Owing to the radial construction of the false stem and the complex structure of the cortex, *Tempskya Wessellii* obviously belongs to the *grandis-Rossica* group of *Tempskya* as outlined by Read and Brown

(17, p. 119). It differs from the species they placed in this group, however, in having smaller stems and longer internodes, and from *T. grandis* in particular in having two bands of stone cells in the inner cortex. This last character is believed sufficient to justify placing the material in a new species. With respect to size of stems and length of internodes some resemblance to *T. Knowltoni* and *T. minor* may be noted, but these species lack the stone cells in the inner cortex, and the arrangement of the stems is such as to indicate that the false stems grew in a dorsiventral position (Read and Brown, 17). It is apparent from the combination of characteristics present in *T. Wesselii* that stem size and length of internodes are not always linked with the habit of the false stem. As yet we know of no species with large stems and short internodes that have the dorsiventral habit. The dorsiventral forms, on the other hand, may all have small stems, although small stems are not confined to this group.

In view of the fact that the main distinguishing feature of *Temp-skya Wesselii* is the double layer of stone cells in the inner cortex, this tissue will be described in some detail (Pl. IX, Figs. 1-2). The whole inner cortex is about one third of a millimeter in extent, although it varies somewhat in different stems and in different parts of the same stem. The outermost sclerenchyma layer is a thin, somewhat irregular band generally not exceeding three or four cells in breadth, which appears to lie along the transition zone between the middle and the inner cortical layers. Whether it belongs to the middle or the inner cortex is not absolutely clear, but the assumption is that it belongs to the inner zone (Pl. IX, Fig. 2). The cells are fairly large and angular and have thick walls and small lumina. Read and Brown refer to them as "gummy sclerenchyma," apparently because of their homogeneous appearance where they are not well preserved and the brownish color of the walls. However, when specimens are examined carefully in thin section, numerous canal-like pits may be seen penetrating the thick walls, indicating that these cells are true stone cells, although in the less well-preserved ones partial disintegration of the wall gives the appearance of a gummy substance. The cells of the inner sclerenchyma layer resemble the outer ones except that they form a band of cell clusters which are isolated from one another by a distance about equal to or slightly less than their own diameter. A peculiarity in the chemical make-up of these stone cells is that in sections prepared by the

"peel" method they are not recognizable, which indicates that they are soluble in the hydrofluoric acid used in the etching process. Consequently, if only peel sections were studied, this species would not show its main distinguishing feature.

Between the two stony layers of the inner cortex is a homogeneous tissue of rounded or oval thin-walled cells with dark foamy contents (Pl. IX, Fig. 2). They vary somewhat in size and tend to be flattened against one another in radial rows. Between cells of adjacent rows there are numerous rather large intercellular spaces.

The inner cortex is succeeded on the inside by the outer endodermis, which in places is well preserved as a single layer of small thin-walled cells with dark contents. Between the endodermis and the xylem is a zone of thin-walled cells which represents the pericycle and phloem, but these tissues cannot be distinguished from each other.

In the stems of the holotype specimen most of the xylem has disappeared, the space having become filled with clear silica (Pl. VIII, Fig. 1; Pl. IX, Fig. 1). The disintegration of the xylem is difficult to explain when the excellent preservation of the other tissues is considered. Nevertheless, small portions are present in which the structure is well revealed. One or more parenchyma cells are usually present in contact with each tracheid. These cells are sometimes isolated and in contact with the shorter tracheid walls, although frequently they occur as chains of three or more cells. Read and Brown place some stress on the prevalence of xylem parenchyma in specific diagnoses. *T. grandis* and *T. Rossica*, according to them, contain much xylem parenchyma, whereas in *T. Knowltoni* and *T. minor* there is said to be little or none. It is evident from the material of *Tempskya* available for study that there is some variation in the amount of parenchyma in the different species, but whether this character is one of value in distinguishing between species may, it seems, be questioned unless material of the species concerned is available for direct comparison. Because the parenchyma cells are rather regularly distributed among the tracheids — sometimes singly, sometimes in chains of two, three, or more — it is seldom possible to express the condition in concise terms. This difficulty is illustrated by the statement by Read and Brown that in *T. Knowltoni* the xylem parenchyma is composed "almost entirely of scalariform tracheids with almost no xylem parenchyma." This statement might mean either that parenchyma cells are difficult to find in *T. Knowltoni* or

that the total amount of parenchyma is small because of the smaller size of the cells as compared to the proportion of tracheids making up the tissue. It is obvious, however, that in *T. Knowltoni* parenchyma cells are of frequent occurrence in the xylem, but they are usually isolated cells, or sometimes two cells may occur together. In such species as *T. grandis* and *T. Wesselii* the parenchyma cells may form chains of three or, occasionally, more cells which separate the tracheids, but the continuity of the tracheid tissue is not interrupted to any extent.

Lining the inside of the xylem ring is a narrow zone of thin-walled cells apparently consisting of phloem and pericycle, and this is succeeded by the internal endodermis. The endodermis surrounds the pith, which consists of a narrow outer zone of thin-walled cells enclosing the inner sclerenchymatous part. The thick walls of the sclerenchyma are perforated by numerous burrow-like pits.

The form and departure of the frond traces are identical in all essential respects with those of other species of *Tempskya* (Pl. VIII, Fig. 1). Completely detached petioles are but rarely found in the sections. The xylem arc of the petiole base is a thin broadly horse-shoe shaped band slightly flattened abaxially, with the ends slightly enlarged. At this stage they are not curved inwardly, and it seems doubtful that even in the free petiole the extremities become as strongly incurved as those in *T. grandis* and *T. Rossica*, although the exact condition is unknown above the petiole base.

The cortex of the petiole base shows the same structural differentiation as that of the stem, including even the two layers of stone cells in the inner cortex. The outer stony layer is continuous all the way around, but the inner one extends only as far as the xylem arc. No stone cells can be seen along its concave adaxial surface or in the gap between the extremities of the xylem.

The roots of *Tempskya Wesselii* are well preserved and resemble those of *T. grandis*, which are well illustrated by Read and Brown (5, Pl. 41, Fig. 4). The diarch stele is enclosed by a thick sclerenchymatous cortex, which is bounded on the outside by a layer of large-celled parenchyma (Pl. VIII, Fig. 2). This parenchymatous layer seems to vary considerably in extent. In many roots it has been wholly or partly torn away, and the remaining portions are usually crushed. In a few roots, however, the tissue is complete and forms an outer cortical zone about equal in extent to the sclerenchyma.

No filiform root hairs, such as Read and Brown figure in connection with *T. minor*, have been seen in *T. Wessellii*. This outer cortical parenchyma also extends as strips of crumpled tissue into the spaces between the roots and constitutes the binding tissue of the root mass. Apparently, as new roots grew downward among the older roots, they often penetrated this outer layer, and thus pulled it away from the roots to which it had originally been attached and in many instances tore it loose completely. The outer cortex of these younger roots was in turn penetrated by other roots, with the result that very little of it remains in place.

The foregoing interpretation of the binding tissue of the root mass of the false stem seems to be supported in material identified as *Tempskya grandis* from Wheatland County, Montana (Pl. XI, Fig. 2). In this material preservation is superior to that of any other specimen so far observed, and sometimes two or more roots are surrounded by a common layer of parenchyma which has become distended beyond its original limits. These roots also bear root hairs.

*Tempskya wyomingensis*, sp. nov. (Pl. X; Pl. XI, Fig. 1). — The material assigned to this species consists of several false stem fragments which were found about twenty miles northeast of Greybull, Bighorn County, Wyoming. The area which yielded the remains lies principally within the valley of Beaver Creek, a southerly flowing tributary of Shell Creek. The eastern portion of the Bighorn Basin lying between Sheep Mountain, just north of Greybull, and the Bighorn Range consists of a shallow syncline in which the sediments range from Paleozoic to Cretaceous. The rocks covering most of the syncline belong to the Colorado group, and beneath it are the Cloverly and the Morrison formations. These latter formations outcrop as a narrow band along the eastern margin of the basin, where they were tilted up by the elevation of the Bighorn Range, but in the vicinity of Beaver Creek they are uncovered over a larger area.

Fragments of *Tempskya* are widely scattered within the valley of Beaver Creek and its tributaries, but they are nowhere abundant. They have been found only where the Morrison formation is exposed and are associated with enormous numbers of dinosaur bone fragments and gastroliths; in fact, a few small pieces were found only a mile or two from the quarry of the Sinclair Dinosaur Expedition of 1934 (Brown, 5). Also associated with the fern material are occa-

sional fragments of the trunks of *Cycadeoidea*, which resemble those from the Freezeout Mountain locality north of Medicine Bow.

The author is indebted to Mr. and Mrs. F. W. Dennler, of Greysbull, for most of the material of *Tempskya wyomingensis*. Another specimen was submitted by Mr. H. Timmel who, with Mr. Leslie Couch, acted as a guide in the Beaver Creek locality in 1941.

The material is not so well preserved as that of *Tempskya Wesseli*, and some of the histological details admirably displayed by that species are obscure in this one. The xylem cylinder, however, is well preserved, and the false stems had suffered little or no crushing.

*Tempskya wyomingensis* is very close to *T. grandis*, and specific separation is made only after considerable deliberation. Its diagnosis is as follows:

False stems radially symmetrical; individual stems 6-8 mm. in diameter, internodes short, with 1-4 leaf traces appearing in each transverse section; free phyllopodia frequent; cortex three-layered; inner layer, which constitutes less than one half of the cortical zone, bounded on outside by a narrow but continuous band of stone cells, and on inside by a discontinuous band occupying one half of the width of the layer; endodermis not visible; xylem with considerable interspersed parenchyma, 5-8 cells in extent, and with an almost continuous zone of small tracheids around periphery; inner and outer phloem and pericycle present; pith mostly fibrous; xylem strand of free petioles (phyllopodia) with strongly incurved margins; roots provided with filiform root hairs.

Holotype No. 23400, Univ. Mich. Coll.

As already stated, this species is close to *Tempskya grandis*, and were it not for the double layer of stone cells in the inner cortex (a feature it shares with *T. Wesseli*) it would be placed within that species without hesitation. Its internodes were evidently shorter than those of *T. Wesseli*, but longer than those in *T. grandis*, though it is possible that there was some variability with respect to this feature, as is indicated by the fact that the number of leaf traces per stem section varies from one to three (Pl. XI, Fig. 1). It is difficult to utilize such features as length of the internodes and amount of parenchyma present in the xylem for separating species because of the lack of absolute standards for comparison.

*Tempskya wyomingensis* agrees with *T. grandis* in the radial construction of the false stems, in having large stems (6-8 mm. in

diameter), in having large petiole bases (four fifths of the diameter of the stem), and in the relatively short internodes. A feature it possesses in common with *T. minor*, one of the dorsiventral species, is the presence within the root mass of free petioles (Pl. X, Fig. 1; Pl. XI, Fig. 1). These generally lie near the stems. Its point of agreement with *T. Wesselii* is the double layer of stone cells in the inner cortex, but it disagrees markedly in size of stems.

In the preceding descriptions of the two new species of *Tempskya* stress is placed upon characteristics which are believed to distinguish them from previously described species, and no effort is expended in elaborating upon the general morphology of the false stem or the more obvious anatomical structure of the vascular system. These phases have been adequately dealt with by previous authors. The main result of this study has been to give a better idea than we have had before of the variety of structures exhibited within the genus which are believed important in separating species, and also to show that in most instances the species can be identified only upon microscopic examination. The segregation of the species by Read and Brown into two groups — those with radially symmetrical false stems and those with the dorsiventral habit — is believed to be basically sound, but with the addition of two new species to the radially symmetrical group this one is now the larger. It appears, however, that the associated characteristics attributed to this group by Read and Brown do not hold because, as shown by *T. Wesselii*, some of its members have small stems with long internodes. Shorter internodes seem to accompany the larger stems.

Aside from stem size and internode length, which are relative characters and cannot be well expressed in absolute terms, the most dependable basis for specific separation seems to rest in the structure of the cortex. *Tempskya grandis*, *T. Wesselii*, and *T. wyomingensis* all agree in having a three-layered cortex, but the last two are distinguished from the first one by the presence of the double layer of stone cells in the inner zone. *T. Wesselii* and *T. wyomingensis*, on the other hand, are distinguished from each other by stem size and length of internodes. It is unfortunate that Kidston and Gwynne-Vaughan (12) failed to give a more complete account of the cortex of *T. Rossica*. No mention is made of sclerenchyma in this tissue, although a close inspection of one of their figures (Pl. I, Fig. 4) gives the impression of two sclerotic layers such as occur in *T. Wesselii*.

*selii* and *T. wyomingensis*. It is impossible, however, to be certain of this because of the low magnification at which the tissues are shown and the rather inferior preservation that is evident.

When describing species of fossil plants one is perpetually confronted with the problem of how much structural variation to permit to enter into the specific diagnosis or how finely to draw specific distinctions. Accordingly, species are narrowly or broadly interpreted. In describing leaf impressions from the Tertiary the amount of variation that may be encompassed within a species may be judged by the range of variation displayed by the nearest living equivalents. The problem is somewhat different with anatomical material because inside the plant body the range of variation is usually considerably less and, moreover, some species are much alike so far as vascular anatomy is concerned. It appears, therefore, that constant anatomical differences, even though they may be slight, indicate distinct species. A case in point is demonstrated by *T. Wesselii* and *T. wyomingensis*, which have the double band of stone cells in the inner cortex. This relatively inconspicuous feature appears constantly throughout the stems of both species, and in the living condition was no doubt accompanied by distinctive features of the fronds or sporangia which set these apart from others.

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## EXPLANATION OF PLATE I

FIG. 1. *Osmundites oregonensis*, sp. nov. Holotype. Slightly enlarged

FIG. 2. Portion of holotype specimen shown in Figure 1, at a slightly lower level. Enlarged to show the leaf bases.  $\times 3$

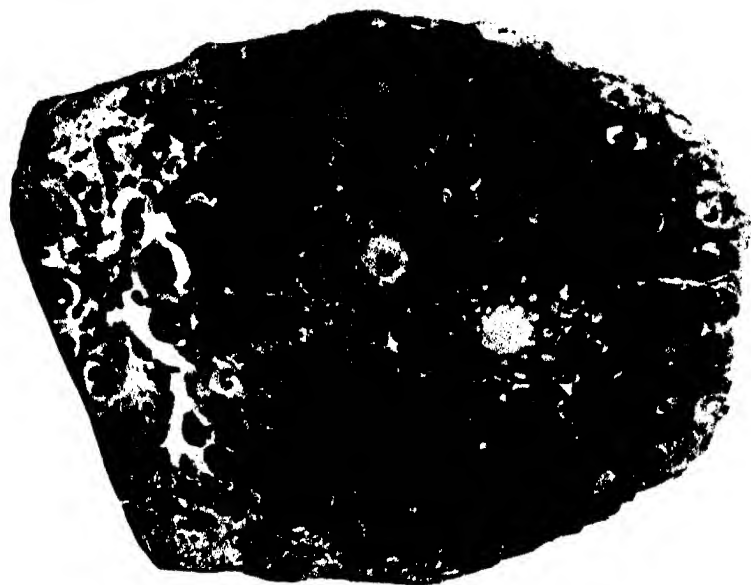


FIG. 1



FIG. 2

## EXPLANATION OF PLATE II

FIG. 1. *Eorhachis lomarioides*, gen. et sp. nov. Holotype.  $\times 3$

FIG. 2. *E. lomarioides*, gen. et sp. nov. Portion of holotype specimen illustrated in Figure 1, showing peripheral bundles and three inversely oriented bundles in the interior. The air spaces in the ground tissue are visible.  $\times 20$

*Eorhachis lomarioides*

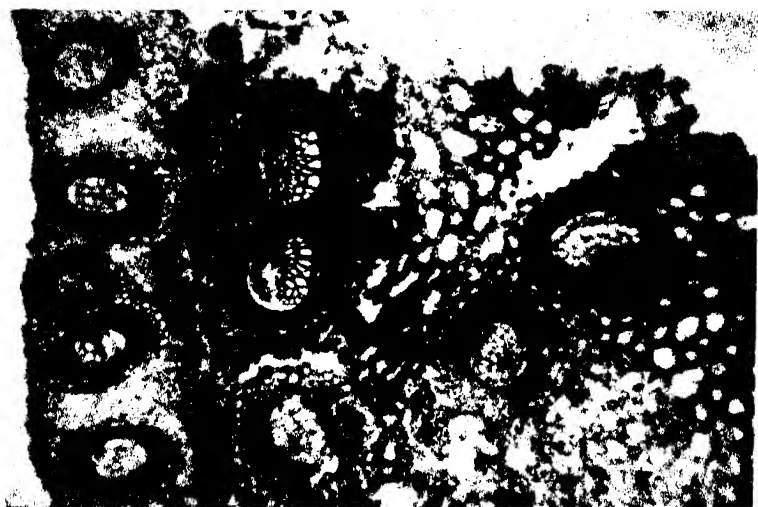
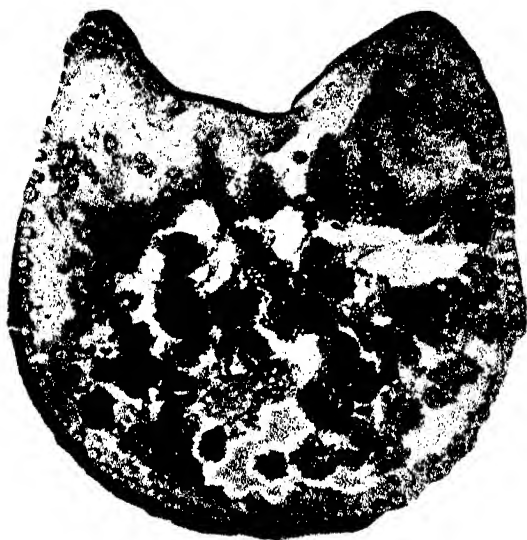


FIG. 2

### EXPLANATION OF PLATE III

*Cyathodendron texanum*, gen. et sp. nov. Portion of short stem showing  
external features.  $\times 1$



## EXPLANATION OF PLATE IV

FIG. 1. *Cyathodendron texanum*, gen. et sp. nov. Transverse section of holotype.  $\times 1$

FIG. 2. *C. texanum*, gen. et sp. nov. Portion of a transverse section, showing the numerous bundles of the medullary region.  $\times 6$

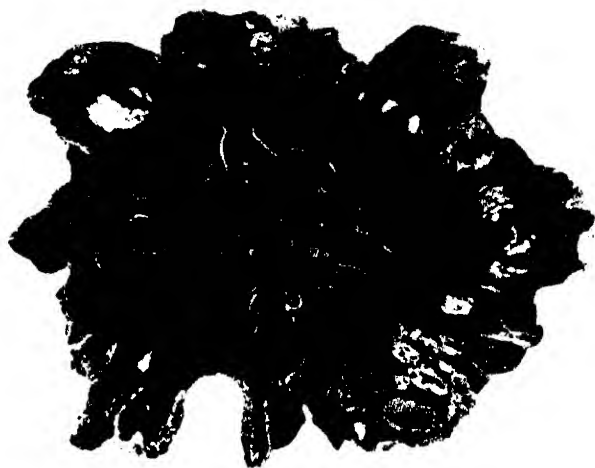


FIG. 1

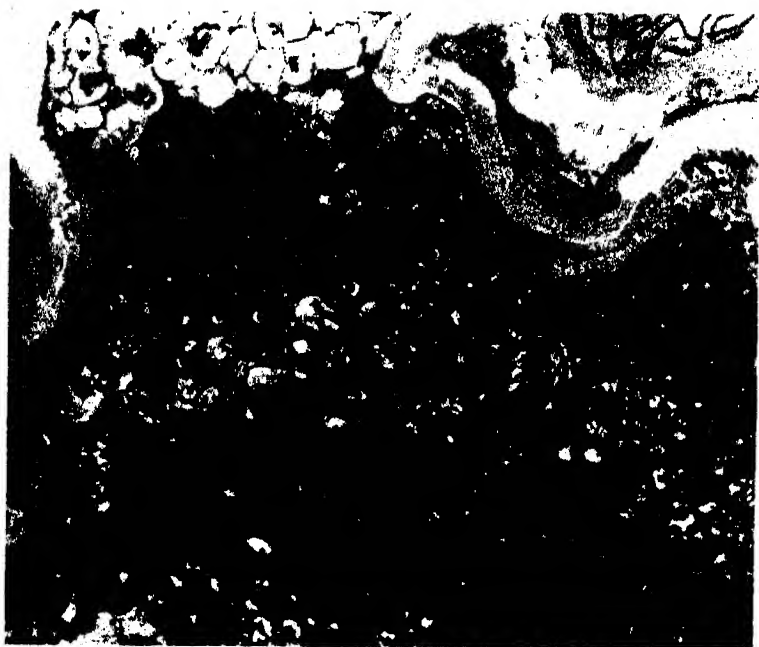


FIG. 2



## EXPLANATION OF PLATE V

- FIG. 1. *Cyathodendron texanum*, gen. et sp. nov. Transverse section, showing the outward prolongation of the solenostele to form the troughlike trace strand, and the numerous medullary bundles passing into the petiole. Paratype.  $\times 3$
- FIG. 2. Section at slightly higher level than that shown in Figure 1. The lower extremity of the compensation tongue appears in the space corresponding to the leaf gap. Holotype.  $\times 2\frac{1}{2}$
- FIG. 3. Section slightly above the level shown in Figure 2. The compensation tongue has closed the leaf gap, and the trace has become detached from the solenostele.  $\times 2\frac{1}{2}$
- FIG. 4. Section just below point of separation of the petiole from the stem, showing the closed solenostele and the leaf trace of separate bundles.  $\times 2\frac{1}{2}$



FIG. 1



FIG. 2



FIG. 3



FIG. 4

### EXPLANATION OF PLATE VI

- FIG. 1. *Cyathodendron texanum*, gen. et sp. nov. Medullary strand in the central part of the stem. Holotype.  $\times 120$
- FIG. 2. Portion of the solenostele of the holotype, showing the xylem, the narrow strip of disintegrated phloem, and the sclerenchymatous sheath.  $\times 125$
- FIG. 3. Portion of the ramentum of multicellular hairs covering the surface between the leaf bases. Holotype.  $\times 80$
- FIG. 4. Portion of the holotype, showing the tracheids in transverse section.  $\times 475$



FIG. 1



FIG. 2



FIG. 3



FIG. 4

## EXPLANATION OF PLATE VII

FIG. 1. *Tempskya Wesselii*, sp. nov. Transverse section of a false stem, from the placer deposits at Greenhorn, Oregon. Paratype.  $\times 1$

FIG. 2. Vascular cylinder of a single stem of the specimen shown in Figure 1.  
 $\times 7$

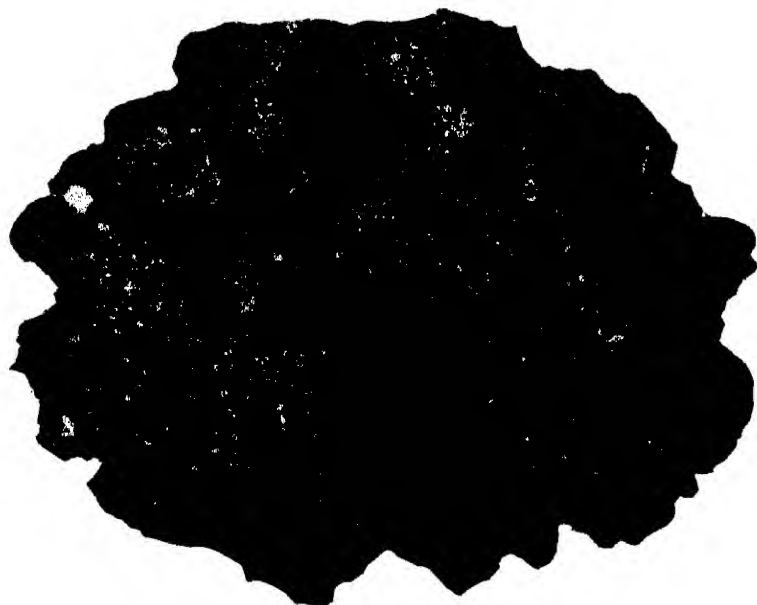


FIG. 1

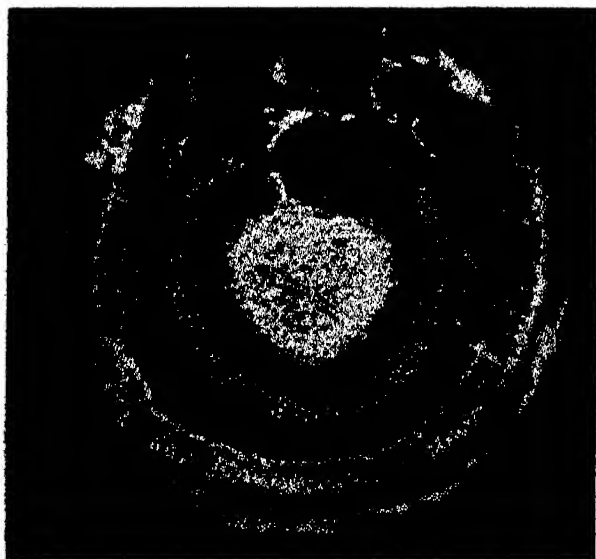


FIG. 2

## EXPLANATION OF PLATE VIII

FIG. 1. *Tempskya Wesselii*, sp. nov. Transverse section of two stems embedded within the root mass. From Great Falls, Montana. Holotype.  $\times 9$

FIG. 2. Root mass of specimen shown in Figure 1.  $\times 24$

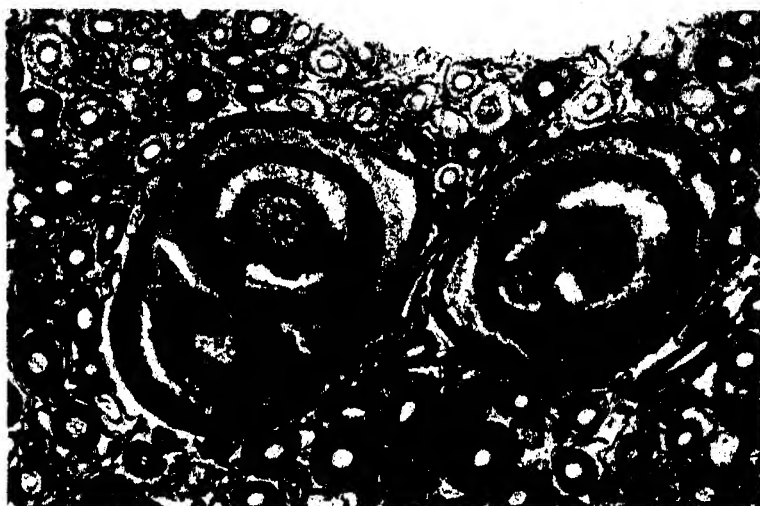


FIG. 1



FIG. 2



## EXPLANATION OF PLATE IX

- FIG. 1. *Tempakya Wesselii*, sp. nov. Transverse section of stem, showing the three layers of the cortex. Most of the xylem tissue has disappeared. Holotype.  $\times 63$
- FIG. 2. Portion of the inner cortex of the specimen shown in Figure 1, enlarged to make clear the two bands of stone cells.  $\times 110$

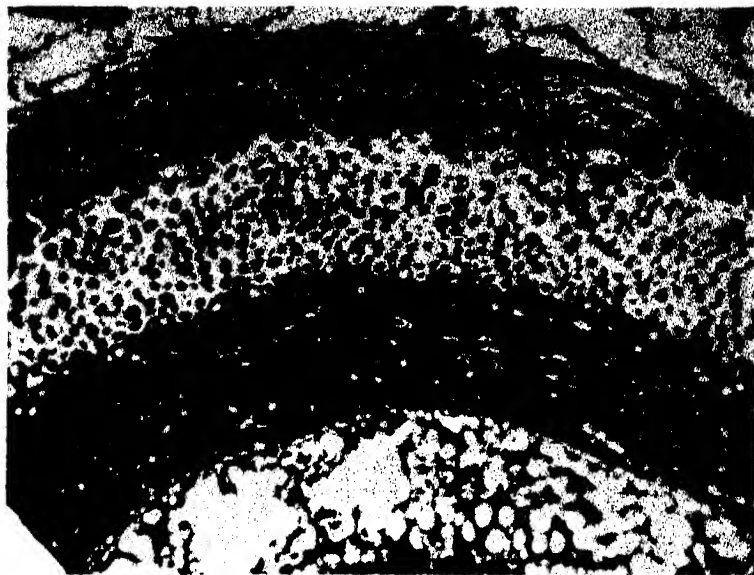


FIG. 1

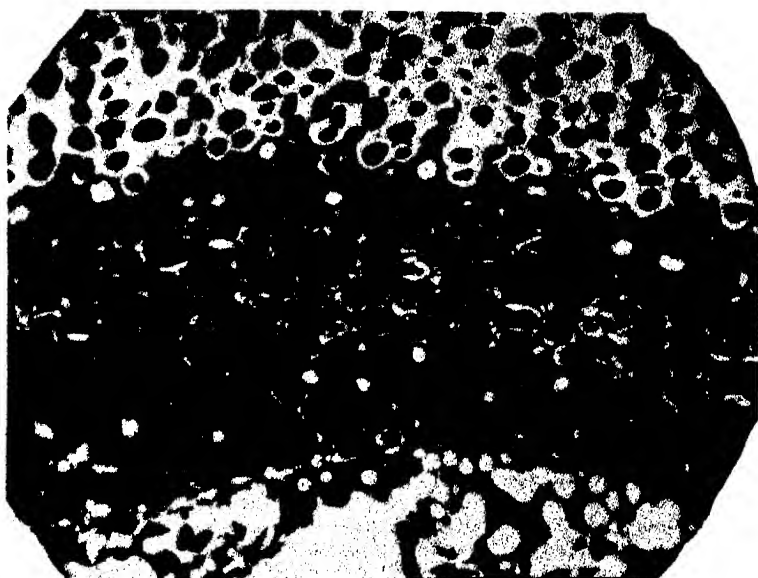


FIG. 2

## EXPLANATION OF PLATE X

FIG. 1. *Tempskya wyomingensis*, sp. nov. Transverse section of the stem, showing two departing traces and a detached petiole (phyllopodium). Holotype.  $\times 6$

FIG. 2. Two stems from the holotype, showing departing traces and adventitious roots.  $\times 6$

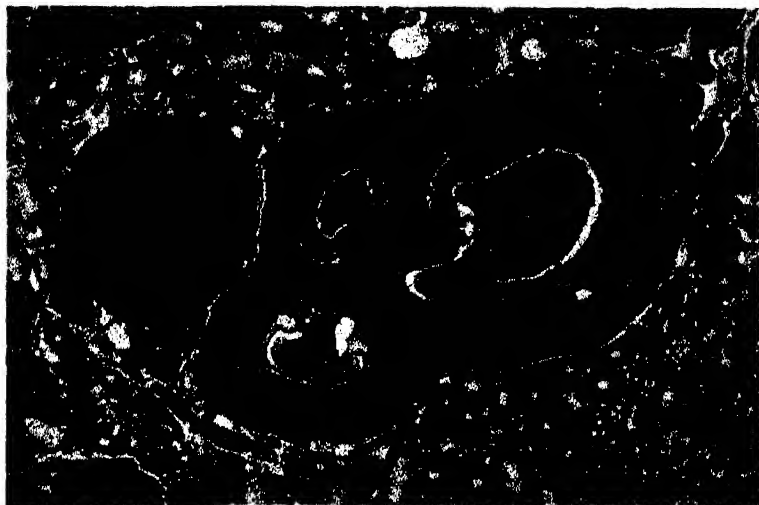


FIG. 1

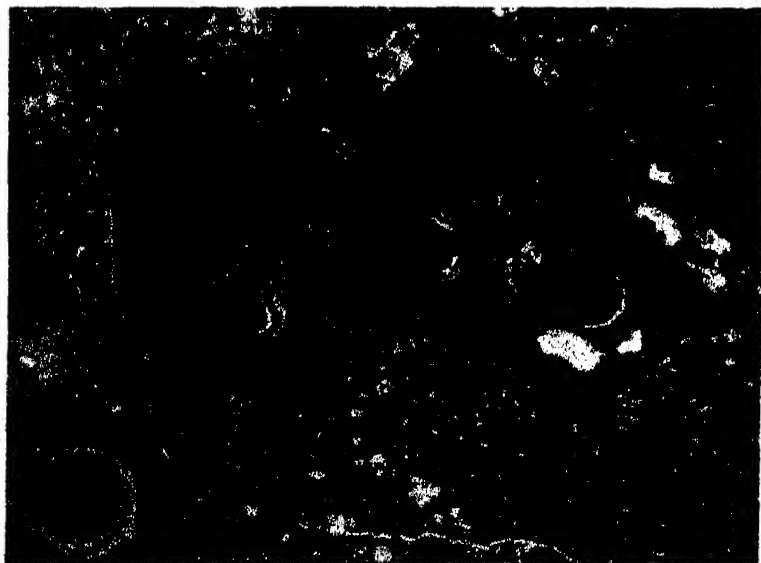


FIG. 2

## EXPLANATION OF PLATE XI

- FIG. 1. *Tempskya wyomingensis*, sp. nov. Portion of false stem, showing several stems and petioles embedded within the root mass. Holotype.  $\times 2\frac{1}{2}$
- FIG. 2. *T. grandis* Read et Brown. Section showing two or more roots surrounded by a common layer of parenchyma. Root hairs are visible in places. Material from Wheatland County, Montana. No. 23400 Univ. of Mich. Coll.  $\times 25$

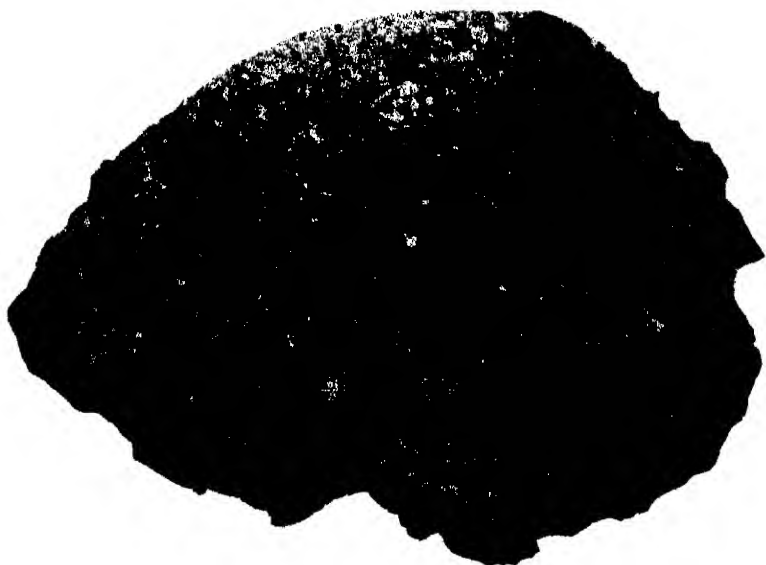


FIG. 1

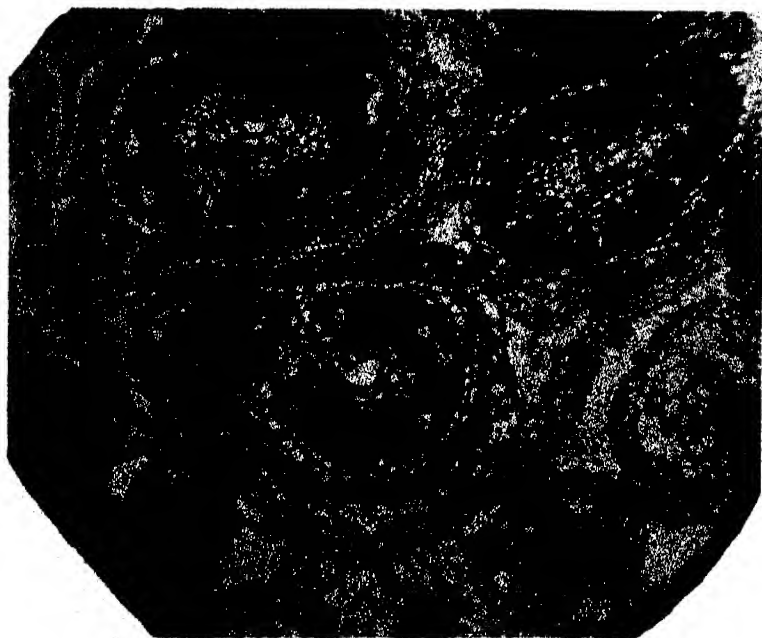


FIG. 2



## PACIFIC SPECIES OF GALAXAURA

### I. ASEXUAL TYPES \*

RUTH CHEN-YING CHOU

**T**HE genus *Galaxaura*, comprising calcified members of the Chaetangiaceae (Rhodophyceae), is morphologically of great interest to the botanist, although economically unimportant. The first specimens that were scientifically described were treated as polyps by Ellis and Solander (1786), under the name *Corallina* — a genus which, when first established by Linnaeus, contained all polyp-like animals and plants, but which is now entirely limited to a restricted genus *Corallina*, a group of calcareous red algae. After Ellis and Solander all naturalists working with the polyps adopted their classification, with the exception of Gmelin (1788) and Esper (1830), who put some of the species with *Tubularia*, which, in modern literature, is an animal genus of Hydrozoa (Coelenterata). In 1812 Lamouroux properly evaluated these so-called "polyps" as at least a distinct genus in a newly established family Corallineae, which included several genera of coralline algae. Nevertheless, like his contemporaries, he was not ready to give up the idea that these plants were animals, and so he regarded his family Corallineae as made up of "polypiers phytoides," or plantlike polyps.

For over three years I have given much time to a taxonomic study of the genus, hoping to bring together all these marine plants and their descriptions for a revision. Unfortunately, the spread of the war throughout the areas inhabited by them has made them unavailable and rendered it impossible to obtain additional working material or to borrow type specimens. Consequently, the intended scope of research has been narrowed down to include only the Pacific species of *Galaxaura*.

This investigation covers the *Galaxaura* flora of both the west and the east sides of the Pacific basin. A collection from the Philip-

\* Papers from the Department of Botany and the Botanical Garden of the University of Michigan, No. 740.



pine Islands made by Professor H. H. Bartlett in 1935, together with collections from Java and Sumatra by Kostermans in 1938, typifies the *Galaxaura* flora of the western part of the tropical Pacific Ocean. Professor W. R. Taylor's specimens, secured by him on the Hancock Expedition in the years 1934 and 1939, are representative of the flora found along the eastern part of the tropical Pacific Ocean. In the materials from these two sources are eleven asexual species, including three new ones, and ten sexual species, with one new. To both gentlemen I am much indebted for furnishing materials for this investigation and for reviewing the manuscript. Special thanks are due to Professor Taylor for his critical guidance throughout the course of this study and to Professor Bartlett for other assistance. I am deeply grateful to the Levi Barbour Oriental Girls' Scholarship Fund of the University of Michigan, under which part of the research was carried on.

The plants of the genus *Galaxaura* are widely distributed in tropical and subtropical waters. They occur in the latitudes between 40° N. and 40° S. — northward as far as Japan and southward to Australia and the Cape of Good Hope, Africa.

The taxonomy of these plants is very incompletely known because the species within each division lack clear, definite differentiating features. Some plants may look identical in gross habit, but be entirely different in their cellular structure, as are members of the sections *Arboreae* and *Vepreculae*. Others may vary externally, but be similar in their structural organization, for example, *G. barbata* and the flattened species of the *Arboreae* or plants in the *Oblongatae* section.

The taxonomy is further complicated by the sexual dimorphism of the plants, first adequately demonstrated by M. A. Howe (1916, 1918). It is quite probable that the species are only half as numerous as the specific names hitherto proposed, but because of dimorphism each plant has received two names — one for the asexual and one for the sexual generation of the life cycle. The exact correspondence between the presumed alternate generations cannot be settled for individual species without comprehensive studies in the field with this point in view, or else without cultural studies. It cannot be settled by a comparison of herbarium specimens. In view of this fact the plants have had to be arbitrarily separated into sexual and asexual groups of nominal species. Each recognizable assemblage

of morphologically distinct plants is treated as an independent individual while we are awaiting recognition of the other phase in the life cycle. Whenever pairing is plausible it is mentioned in the discussions; Howe's hypothesis of sexual dimorphism is therefore tested so far as possible with herbarium materials.

In the *Galaxaurae*, because of the uncertainties of their life history, no attempt is here made toward the interpretation of the synonymy. All the species hitherto established, some doubtful as they may be, are maintained, and the identification of the plants on hand depends entirely on how closely they fit the type descriptions.

This paper (Part I of the whole study) deals with the asexual types only; the sexual plants will be treated in Part II, to appear in a later publication, which will complete the record of the Pacific species of *Galaxaura*.

#### NOMENCLATURE OF THE SECTIONS

It is to be regretted that Kjellman did not pay very much attention to the choice of sectional names when he wrote his monograph on *Galaxaura*. Of the sectional names used by him some are in correct form, as recommended by the International Rules, i.e. adjectives (preferably taken from representative or best-known species) in the plural, but other coördinate names are such as would be proper for subgenera, namely, substantives in the singular. Not only is it objectionable to have these two types of names used for coördinate generic subdivisions of the same category, but it is not appropriate to intersperse with them, as Kjellman did, some Latin adjectives used in the singular as substantives and others in the plural, apparently in the neuter gender instead of the feminine, as they would have to be in the genus *Galaxaura*.

I therefore propose certain modifications of Kjellman's sectional names, with the understanding that such names as *Rhodura* and *Microthoë* would be available for consideration as retained subgeneric names in a natural classification based upon characteristics of both the sexual and the nonsexual phases of the species. The amended list of sections is as follows:

Subverticillatae for *Rhodura*  
Squalidae for *Microthoë*  
Oblongatae for *Eugalaxaura*  
Arboreae for *Brachycladia*

Vepreculae (no change)  
 Angustifrones for Laevifrons  
 Robustae for Dichotomaria Cameratae  
 Umbellatae for Dichotomaria Spissae

It is to be noted that the type or standard species of *Galaxaura* is *G. umbellata*. This species must therefore be included in any subgenus named *Eugalaxaura*, if the rules and ordinary usage are to be followed. Kjellman's classification does not include *G. umbellata* in his section *Eugalaxaura*, and so it is necessary to suppress his subgenus by this name; reconstituting it with the type included would only cause confusion.

## KEY TO THE SPECIES OF GALAXAURA

### ASEXUAL TYPES

Plants asexual or tetrasporic; branches terete throughout or flattened above, villous or glabrous; short assimilatory filament either of the type of the Subver-

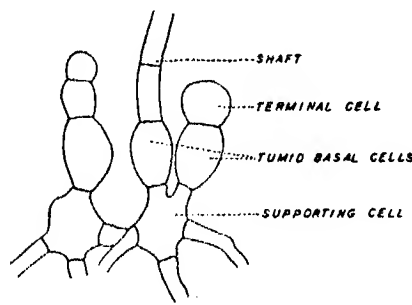


FIG. 1. Type of the Subverticillatae

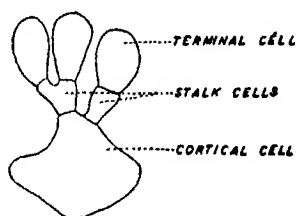


FIG. 2. Type of the Arboreae

ticillatae (Fig. 1), composed of a tumid basal cell and one or two terminal cells, or of the type of the Arboreae (Fig. 2), composed of stalk and terminal cells.

- |                                                                                                                                                                  |                                      |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|
| 1. Plants with branches terete throughout                                                                                                                        | 2                                    |
| 1. Plants with branches flattened above, although terete below                                                                                                   |                                      |
| (Section Arboreae)                                                                                                                                               | 8                                    |
| 2. Branches glabrous, robust, 2-4 mm. thick; segments turgid, articulate, or subarticulate                                                                       | (Section Robustae) <i>G. robusta</i> |
| 2. Branches villous or hirsute, bearing extended assimilatory filaments; slender, not over 2 mm. in diameter                                                     | (Section Subverticillatae) 3         |
| 3. Assimilatory portion homogeneously filamentous, composed only of extended assimilatory filaments; supporting cells undifferentiated; tumid basal cells absent | <i>G. filamentosa</i>                |
| 3. Assimilatory portion heterogeneous, composed of both extended and short assimilatory filaments; supporting and tumid basal cells present                      | 4                                    |

4. Short assimilatory filaments of the type of the Arboreae (Fig. 2); extended filaments verticillate at base of each proliferation . . . . *G. barbata*
4. Short assimilatory filaments of the type of the Subverticillatae (Fig. 1); extended assimilatory filaments all over the thallus . . . . . 5
5. Terminal cells of short assimilatory filaments wider than basal cells; both extended and short assimilatory filaments fasciculate *G. fasciculata*
5. Terminal cells of short assimilatory filaments subequal or narrower than basal cells; short and extended assimilatory filaments not fasciculate . . . . . 6
6. Short assimilatory filaments predominantly two-celled, rarely three-celled . . . . . *G. ramulosa*
6. Short assimilatory filaments commonly three-celled, some two-celled . . . . . 7
7. Short and extended assimilatory filaments subverticillate; terminal cells of short assimilators smaller, narrower than basal cells . . *G. subverticillata*
7. Short assimilatory filaments few, evenly scattered among the extended ones; terminal cells variable, subequal, narrower, or wider than basal cells . . . . . *G. subfruticulosa*
8. Cortical tissue 20-60  $\mu$  thick, 1-2-stromatic . . . . . 9
8. Cortical tissue 60-80  $\mu$  thick, 2-3-stromatic . . . . . *G. spathulata*
9. Thallus 2.0-3.5 mm. wide, angles wide; terminal cells of the short assimilators often apiculate . . . . . *G. apiculata*
9. Thallus 1-2 mm. wide, angles round or acute; terminal cells of the short assimilators round or acute . . . . . 10
10. Branches continuous, proliferations few . . . . . *G. arborea*
10. Branches proliferous, constricted, or subarticulate; upper parts sometimes continuous; proliferations at the base surrounded by tufts of extended assimilatory filaments . . . . . *G. stipicaulis*

### *Galaxaura filamentosa*, sp. nov. -- Pl. I,

Figs. 1-6; Pl. VI, Fig. 1

"*Galaxaura rudis* Kjellm." as misidentified by Tanaka, 1936, p. 145, figs. 1-2; pl. 34, fig. 1; Tseng, 1941, pp. 85-86, fig. 1.

Planta 3.5-5 cm. alta ad substratum disco adfixa, frondibus teretibus cum filamentis assimilatoriis dense vestitis; dichotome ramosis vel interpositione rami adventivi ut videtur trichotome ramosis; internodiis 2-10 mm. longis, 0.5-1.5 mm. crassis (filamentis liberis haud inclusis); thallo ex filamentis in parte media intertextis, in parte exteriori parallelis constato sed structura homogeneo sine cortice; filamentis axialibus 16-24  $\mu$  diam., apice in filamenta assimilatoria chromatophoria transeuntibus per cellulas sustinentes non aut raro maleque differentiatas; absque cellulis basalibus tumidis; parte filamentorum assimilatoriorum libera 1-4.5 mm. longa, simplici vel irregulariter ramosa, ex cellulis cylindricis constante inferioribus 16-18  $\mu$  diam., et superioribus 20-22  $\mu$  diam., sesquiplo vel triplo

longioribus quam crassioribus. Specimen typicum legit W. R. Taylor, no. 39-46, in republica Mexicana, in loco dicto Sulphur Bay, Clarion I., Revilla Gigedo Ins., Mar., 1939; in herb. "Hancock Foundation," Univ. South. Calif.; duplum in herb. Univ. Mich.

Plants bushy, 3.5-5.0 cm. high, attached by a small discoid hold-fast; fronds terete, throughout densely covered by extended assimilatory filaments; branching more or less dichotomous, sometimes appearing trichotomous by development of adventitious branches; internodes 2-10 mm. long, 0.5-1.5 mm. thick (excluding extended filaments); thallus structurally filamentous, homogeneous, without differentiation of medullary and cortical layers; axial filaments 16-24  $\mu$  in diameter, their free ends extended into assimilatory chromatophore-bearing filaments with poorly developed or undifferentiated supporting cells; tumid basal cells totally absent; shaft of the assimilatory filaments 1.0-4.5 mm. long, simple or branched, composed of cylindrical cells, basal part 16-18  $\mu$  in diameter, the upper 20-22  $\mu$  in diameter, the length of individual cell 1.5-3 times as long as the diameter.

This new species is anatomically simpler than all the Subverticillatae hitherto described. Phylogenetically it may be closely related to Kjellman's *G. rudis* from the vicinity of Tonga, under which name the plants have undoubtedly been reported. The present investigation, however, shows that the assimilatory filaments of the Mexican and the Ecuadorian plants have only poorly developed or undifferentiated supporting cells, and the tumid basal cells, which are prominent in all other species, are entirely absent; thus the thallus is homogeneously filamentous throughout, with no differentiation between medullary and cortical tissues. Because of this I have considered these plants from the northern Pacific waters distinct from *G. rudis* of the southern Pacific; the latter species is clearly illustrated and described by Kjellman as having well-developed supporting and tumid basal cells.

Tanaka (1936) and Tseng (1941) reported the collecting of *G. rudis* in Formosa and on Hainan Island, respectively. Both authors have stated that their plants differ from Kjellman's *G. rudis* of the southern Pacific in having undifferentiated tumid and supporting cells. Therefore I am strongly inclined to think that the Chinese and the Formosan plants are identical with the Mexican and the Ecuadorian plants, or, at least, are distinct from *G. rudis*.

*Specimens studied.* — MEXICO: Sulphur Bay, Clarion Island, Revilla Gigedo Isands, *Taylor 39-46* (TYPE), March 17, 1939; COSTA RICA: Golfo Dulce, *Taylor 39-93*, March 26, 1939; Port Culebra, *Taylor 34-533*, Feb. 24, 1934; ECUADOR: Isabela Island, Archipelago de Colon, *Taylor 34-110*, Jan. 12, 1934.

*Further distribution.* — Formosa, Hainan Island.

***Galaxaura subfruticulosa*, sp. nov. — Pl. II,  
Fig. 6; Pl. VIII, Fig. 2**

Kjellman, 1900, pp. 51-53, pl. 4, figs. 4-16, pl. 20, [fig. 19; (probably) Tanaka, 1936, p. 148, figs. 7-8, pl. 35, fig. 2; Tseng, 1941, pp. 87-92, fig. 3.

Plantae 5-6 cm. altae, ad substratum disco crasso adfixae; ramis villosis, saepe irregulariter dichotomis; internodiis 3-12 mm. longitudine; filamentis assimilatoriis aequaliter densis in omnibus thalli partibus; brevibus in partibus vetustioribus, longioribus interdum subverticillatis in partibus apicalibus et in basi proliferationum, longitudine plerumque minus quam 1 mm.; proliferationibus solitariis ad basim depressionum cupuliformium insertis; filamentis medulariis 6-18  $\mu$ , raro 24  $\mu$ , diam.; filamentis peripheralibus ex cellulis sustentibus plerumque male differentiatis etiamque cellulis assimilatorum basalibus tumidis ovoideis vel pyriformibus 45-65  $\mu$  longis, 28-40  $\mu$  crassis constantibus; brevibus filamentis assimilatoriis paucis, inter alia extensa dispersis, 2-cellulis vel 3-cellulis; cellulis terminalibus subglobosis, 20-34  $\mu$  diam., interdum paululo angustioribus quam cellulis subterminalibus atque basalibus; parte filamentum assimilatorii libera simplici vel raro ramosa, basi 14-16  $\mu$  diam., superne 16-18  $\mu$  diam.; cellulis duplo vel triplo longioribus quam crassioribus. Specimen typicum legit W. R. Taylor, no. 34-53, in republica Mexicana, in loco dicto Sulphur Bay, Clarion I., Revilla Gigedo Ins., Jan., 1934; in herb. "Hancock Foundation," Univ. South. Calif.; duplum in herb. Univ. Mich.

Plants 5-6 cm. high; attached to substratum by a broad discoid holdfast; branches villous throughout, often less regularly dichotomous; internodes 3-12 mm. long; the extended assimilatory filaments evenly distributed over the entire surface of the thallus, short on the older parts of the branches, longer and sometimes appearing subverticillate at the apex of the branches and at the base of proliferations, rarely attaining a length of 1 mm.; proliferations singly

emitted, base cupuliform; medullary filaments 6–18  $\mu$ , rarely to 24  $\mu$  in diameter, peripheral tissue consisting of supporting and tumid basal cells of the assimilators, the former commonly not well developed; tumid basal cells oval or pyriform, 45–65  $\mu$  long, 28–40  $\mu$  in diameter; short assimilatory filaments few, scattered among the extended ones, either two- or three-celled, terminal cells subglobose, 20–34  $\mu$  in diameter, equaling or slightly narrower than the subterminal and basal cells; shaft of the extended assimilatory filaments simple, occasionally branched, the basal part 14–16  $\mu$  in diameter, 16–18  $\mu$  above, cells 2–3 times as long as diameter.

These plants from Mexico have offered a real problem in the determination of the species. They share some characteristics with several members of the Subverticillatae, exhibiting no particularly distinctive traits, and still do not coincide satisfactorily with any known species.

In habit the thallus is villous, with the extended assimilatory filaments evenly distributed as in *G. ramulosa*, although the villi of the Mexican plants are not so long as those of *G. ramulosa*. The short assimilatory filaments, which are commonly few, are scantily scattered among the numerous extended assimilatory filaments. They are either two- or three-celled; when two-celled, they resemble the short assimilatory filaments of *G. ramulosa*; when three-celled, those of *G. subverticillata*, except that the terminal cells are subequal or slightly narrower than the subterminal and the basal cells, but not always so narrow as those of *G. subverticillata*. Furthermore, it is not uncommon to find the tumid basal cells bearing lateral branches for terminal cells, and rhizoidal or stoloniferous filaments connecting with adjacent cells or the medullary filaments — a characteristic distinctly exemplified in *G. fasciculata*. All these “mimetic” features complicate the sure determination of the species.

*G. subfruticulosa* may also be more or less closely related to Kützing's *G. tomentosa* from the east coast of Mexico, a species to which I was tempted to refer the present plants from the west coast of Mexico. Kützing's illustration in *Tabulae phycologicae*, Vol. VIII, p. 38, fig. 2, quite evidently shows that *G. tomentosa* does not have any short assimilatory filaments. All the assimilators are long and are composed of moniliform cells, with those near the basal part larger and the filament tapering gradually upward. It is, therefore, quite different from *G. subfruticulosa*.

Again, I was inclined to consider these plants identical with a Japanese species which has been called "*G. fruticulosa* Kjellm." because they agree with that species more closely than with other species of the Subverticillatae. As the studies proceeded, however, I discovered that *G. fruticulosa* was not first established by Kjellman at all, but, rather, is a name given by Lamouroux (1816) to Ellis and Solander's *Corallina fruticulosa* from the Bahama Islands. Curiously enough, whether through an oversight or a typographical error, Kjellman, in describing a Japanese plant, also called it *G. fruticulosa*, adding his own name as the specific authority. In the monograph he disregarded Lamouroux's early *G. fruticulosa* of the Bahama Islands, although, of course, he was familiar with and cited both Ellis and Solander's and Lamouroux's works. Furthermore, Lamouroux's *G. fruticulosa* was originally correctly cited by De Toni in *Sylloge algarum* (Vol. IV, Sectio I, p. 115. 1897). De Toni's work was also cited by Kjellman, so that it is almost unexplainable how he could have neglected the priority of the Bahaman species. This mistake of entirely disregarding the presumably valid early *G. fruticulosa* Lamouroux of the Bahamas and maintaining the distinct Japanese plant under the homonym *G. fruticulosa* Kjellman was made originally by Svedelius (1911), and later in De Toni's *Sylloge algarum*, Sectio V, Additamenta, 1924. The error has been repeated in recent publications, by Tanaka in 1936 and by Tseng in 1941. Regardless of whether or not the Japanese plant under the name "*G. fruticulosa* Kjellm." is identical with the Bahaman plant, the correct citation for the name is *Galaxaura fruticulosa* (Ell. & Sol.) Lamouroux, and if the Japanese plant of Kjellman is different, it must have a new name.

The verification of the Bahaman and the Japanese species would necessitate inspection of both types, and the existence of Ellis and Solander's type of *Corallina fruticulosa* is doubtful. Under such circumstances it seems best to treat these plants from the Pacific waters separately from the West Indian species. In view of this the plants from Clarion Island off the west coast of Mexico are described under a new name. Kjellman's homonymous "*G. fruticulosa*" from Cape Nomo, Japan, as well as Tanaka's *G. fruticulosa* (Japanese plant) and Tseng's from Hongkong and Pratas Island may for the present (pending examination) be considered conspecific.



cells of the assimilators; supporting cells less well developed or undifferentiated, rarely trigonal or quadrate; tumid basal cells oval or elliptical, 40–76  $\mu$  tall, 25–46  $\mu$  wide; short assimilatory filaments commonly three-, rarely two-celled (including tumid basal cell), terminal and subterminal cells smaller than the basal cells; shaft of extended assimilatory filaments simple or sometimes branched above, 15  $\mu$  in diameter toward the base, the upper part 20  $\mu$  in diameter, cells 1–3 times as long as wide.

This species might easily be confused with *G. subfruticulosa*, but can be differentiated because its extended assimilatory filaments form narrow bands alternating with wider bands composed of short assimilatory filaments. The extended assimilatory filaments in *G. subfruticulosa* and other species of the Subverticillatae may sometimes appear to be subverticillate at the upper part of the branches, but these are usually not distinct and are wider than the short assimilatory bands. In other words, the development of extended assimilatory filaments in *G. subfruticulosa* exceeds that of the short assimilatory filaments, whereas in *G. subverticillata* the reverse is true. Furthermore, the short assimilatory filaments in *G. subverticillata* are commonly three-celled, with terminal and subterminal cells distinctly smaller than the tumid basal cell.

*Type locality*. — St. Croix, Virgin Islands.

*Specimens studied*. — PHILIPPINE ISLANDS: Puerto Galera Bay, Mindoro Prov., Bartlett 13787, May 12–17, 1935; Lubang Island, Mindoro Prov., Villaflora 7–8, Aug. 24, 1935; 47, Sept. 11–17, 1935.

*Further distribution*. — Bermuda, Florida, West Indies, Japan, East Indies.

*Galaxaura robusta* Kjellman. — Pl. III,

Figs. 1–10; Pl. IX, Fig. 2

Kjellman, 1900, p. 85, pl. 18, figs. 19–22, pl. 20, fig. 42. Tanaka, 1936, pp. 170–171, pl. 45, figs. 38–39.

Plants up to 10 cm. high, with robust regularly dichotomous branches; basal attachment not seen; thallus cylindrical, becoming flattened when dried, thin, fragile after decalcification; segments plicate, constricted, or subarticulate at the nodes, 0.8–2.0 cm. long, 4 mm. in diameter; medullary filaments commonly 16  $\mu$  in diameter, ranging between 8 and 20  $\mu$ , the majority of them lying close to the periphery; cortical parenchyma monostromatic, cells large, sub-

globose or rectangular in section, 40–50  $\mu$  tall, 75–90  $\mu$  broad, each bearing 1–3 cylindrical stalk cells, 15–20  $\mu$  tall, 8–11  $\mu$  in diameter; terminal cells obconical, 16–18  $\mu$  tall, 30–40  $\mu$  broad at the outer wall, containing large stellate chromatophores with a pyrenoid at the center, cells closely arranged, angular in surface view, forming a layer of epidermis; tetrasporangia soriferous, clavate or obpyriform, 40–60  $\mu$  long, 25–30  $\mu$  in diameter at the upper end; spores tetrapartite, reniform or amygdaliform, 20–25  $\mu$  long, median diameter 10–12  $\mu$ .

The species is known to have branches coarser than those of any cylindrical asexual *Galaxaurae* hitherto described. Since this specimen from Tonga agrees in every noteworthy respect with the description and the illustrations given by Kjellman, it is easily referred to *G. robusta*.

Being an asexual member of the Robustae the species may pair, as suggested by Howe (1916), to complete a life cycle with one of the members of the Umbellatae. One may mention in this connection that there is a sexual specimen (*Bartlett 15022*) from Dalupiri Island, Philippines, which also has very coarse branches, although not quite so robust as those of the Tonga plant, which in many respects would fit the requirements for the sexual phase of *G. robusta*. The Philippine plant which I have called *G. umbellata* (Esp.) Lamouroux will be considered with the sexual plants in Part II.

*Type locality*. — Nossi Bé Island, Madagascar.

*Specimens studied*. — TONGA: Mukualofa, Brooks, in herb. Taylor, 20444, Aug. 27, 1931.

*Further distribution*. — Nossi Bé Island, Malay Archipelago, Formosa, Japan.

***Galaxaura barbata*, sp. nov. — Pl. IV,**

**Figs. 1–7; Pl. VI, Fig. 2**

Plantae 5 cm. altae, ad substratum disco adfixae; ramis teretibus, siccitate ad apicem interdum compressis; plus minusve regulariter dichotomis, barbatis cum filamentis assimilatoriis divergentibus annulos angustos approximatos vel remotos formantibus, segmentis constrictis vel subarticulatis, 3–9 mm. longis, diam. 0.5–1.0 mm.; filamentis medulariis plerumque diam. 12–16  $\mu$ , sed inter 6 et 20  $\mu$  variantibus; cortice monostromatico, cellulis corticalibus grandibus,

ovoideis vel subglobosis, 32–50  $\mu$  diam., cellulas 1 vel 2 subcylindricas vel clavatas stipitiformes ferentibus, simplices vel furcatas; cellulis stipitiformibus aut cellulam singulam terminalem ferentibus aut si furcatis cellulas duas terminales subglobosas vel ovoideas vel clavatas, 28–44  $\mu$  altas, 20–28  $\mu$  diam., confertis, inter se compressis angulatisque, aspectu superficiali ut cohaerentibus; filamentis assimilatoriis divaricatis 1–2 mm. longis, 16–18  $\mu$  diam.; cellulis basalibus tumidis magnis, 90–120  $\mu$  longis, 28–40  $\mu$  diam., saepe granula amylacea includentibus. Specimen typicum legit W. R. Taylor, no. 34–364, ad Insulam Sanctae Mariae, Galapagos Ins., Jan. 27, 1934.

Plants 5 cm. high, attached to the substratum by a discoid holdfast; branches terete, apex sometimes compressed when dried, more or less regularly dichotomous, barbate with extended assimilatory filaments which form narrow rings with close or remote intervals; segments constricted or subarticulate, 3–9 mm. long, 0.5–1.0 mm. in diameter; the medullary filaments commonly 12–16  $\mu$ , ranging from 6 to 20  $\mu$  in diameter; cortical tissue monostromatic, cells large, ovate or subglobose, 32–50  $\mu$  in diameter, each bearing 1–2 clavate stalk cells, 12–24  $\mu$  long, 10–18  $\mu$  in diameter, simply bearing one terminal cell or slightly furcate at the distal end and bearing two; terminal cells subglobose, oval or clavate, 28–44  $\mu$  tall, 20–28  $\mu$  in diameter, much crowded, angular in surface view, appearing coherent with adjacent cells; the extended assimilatory filaments 1–2 mm. long, 16–18  $\mu$  in diameter, shaft cells cylindrical, 1–5 times as long as diameter; tumid basal cells very large, 90–120  $\mu$  long, 28–40  $\mu$  in diameter, often containing starch grains.

The species is a deep-water representative, dredged from a depth of 37 meters. It shows the characters of "Teretes" in habit but of *Arboreae* in structure. Phylogenetically it will probably find its nearest affinity in Kjellman's *G. lenta* from Ceylon Island, which likewise has terete branches throughout, whereas other species of the *Arboreae* all have flattened branches above. Furthermore, the strong development of the extended assimilatory filaments which occur in narrow rings at the lower parts of the branches and at the base of the proliferations distinguishes the present species from the glabrous or subglabrous *G. lenta*. The new species is also distinguished by having very large tumid basal cells, which are between 90 and 120  $\mu$  long and 28 and 40  $\mu$  in diameter. These measurements are, in fact, the greatest in all the plants I have examined.

These two species of terete *Arboreae* may bridge the gap between the *Subverticillatae* and the *Arboreae*. No definite conclusion can be drawn, however, until the life cycle of these algae becomes better known.

I was inclined to interpret the first specimen I saw as a juvenile stage of one of the *Arboreae* species, probably of *G. arborea*, the basal parts of whose branches are subterete and often villous, with rings of extended assimilatory filaments. Later, when a second specimen, collected by Schmitt from the Island of Santa Cruz, in December, 1934, came under my observation, the existence of another species became quite clear, and it is here recognized under a new name.

*Specimens studied.* — ECUADOR: Santa Maria Island, Galápagos Islands, Taylor 34-364 (TYPE), Jan. 27, 1934; Island of Santa Cruz, Schmitt 316-335, Dec. 8, 1934.

*Further distribution.* — So far as is known, it is endemic in the Galápagos Islands.

*Galaxaura stupicaulis* Kjellman.<sup>1</sup> — Pl. V,

Figs. 10-12; Pl. XI, Fig. 1

Kjellman, 1900, pp. 75-76, pl. 14, figs. 1-9, pl. 20, fig. 28.

Plants 6-7 cm. high, attached by a discoid holdfast; branches terete, villous below, flattened above, continuous, or proliferous with subarticulate constrictions, each encircled by a tuft of extended assimilatory filaments; segments 2-7 mm. long, 1-2 mm. wide, carnosose-membranous, margins slightly thickened; the medullary filaments 7-15  $\mu$  in diameter; cortex parenchymatous, 1-2-stromatic, commonly 20-40  $\mu$ , rarely to 60  $\mu$  thick (excluding the stalk and the terminal cells), the inner cells large, subglobose or compressed, 20-44  $\mu$  tall, 25-50  $\mu$  broad, outer cells smaller, subglobose or pyriform, bearing 1-2 stalk cells; stalk cells cylindrical or cuneate-cylindrical, simple or once furcate, unicellular, rarely two-celled, 30-36  $\mu$  tall; terminal cells variable, subglobose, oval or clavate, 20-44  $\mu$  tall, 20-32  $\mu$  in diameter; extended assimilatory filaments 1 mm. long, with one or two tumid basal cells, size 58-76  $\mu$  long, 24-34  $\mu$  in diameter; shaft 15-16  $\mu$  in diameter, cells 2-5 times as long as the diameter.

<sup>1</sup> This name was published by Kjellman as *G. stupocaulon*, which, for the sake of correctness, should be modified to *G. stupicaulis*, since the adjective must agree with the generic name in gender.

In the group of Fruticulosae Kjellman named two species from Brazil, primarily on the basis of morphological differences: *G. frutescens*, characterized by not having decompound proliferations, the internodes 2-3 mm. wide, inconspicuously zonate, the margins not thickened; and *G. stupicaulis*, differentiated by having decompound proliferations, the internodes hardly over 2 mm. wide, distinctly transverse-zonate, and the margins thickened.

The distinctions regarded by Kjellman as specifically important could very easily be fluctuating variations only, and thus bear no taxonomic significance. In the discussion of *G. arborea* I mention that, because of the frequent occurrence of the verticillate-extended assimilatory filaments on these plants and on the Philippine plants, *Bartlett 15009A*, I am tempted to consider the present Costa Rican plants the same as the Philippine *G. arborea*, although the former are more proliferous.

The plants from Costa Rica were collected from intertidal rocks — a zone where plants are constantly subject to tidal and wave action and to periodic exposure; thus growth may not be normal and continuous. Such conditions may account for some of the specimens being extremely proliferous. However, since none of these differences have been tested by collectors in the field, I have, at least for the time being, decided to maintain Kjellman's *G. stupicaulis* and to refer the Philippine plants to *G. arborea*.

Among the collections there are some sexual plants accompanying the asexual ones, which are very probably the sexual phase of the same species. Because of my present treatment of the species these sexual plants are tentatively assigned to the species *G. veprecula*.

*Type locality*. — Bahia, Brazil.

*Type specimen*. — In Areschoug's herbarium, under the name *G. marginata*.

*Specimens studied*. — COSTA RICA: Golfo Dulce, *Taylor 39-90A*, 39-91A, March 26, 1939.

*Further distribution*. — Bahia, Brazil.

*Galaxaura arborea* Kjellman. — Pl. V,

Figs. 1-5; Pl. X, Figs. 1-2

Kjellman, 1900, pp. 72-73, pl. 11, figs. 1-11, pl. 20, fig. 39. Tanaka, 1936, pp. 161-162, figs. 24-25, pl. 40; Tseng, 1941, pp. 94-95, fig. 6.

Plants densely bushy, deliquescent-arborescent, as much as 12 cm. high, attached by a broad, matlike or discoid holdfast; caudex and basal part of branches subterete, villous with rings of extended assimilatory filaments, sometimes subglabrous, above flattened, glabrous, carnose-membranous, continuous or proliferous, base of proliferations encircled by a tuft of extended assimilatory filaments; thallus 1-2 mm. broad, margins thickened, often with distinct transverse striations, at least toward the distal parts of branches; segments elongate-cuneate, 3-10 mm. long, 1.5-2.5 mm. wide; medullary filaments 8-16  $\mu$  in diameter, the cortical parenchyma tissue 20-60  $\mu$  thick, 1-2-stromatic, cells subglobose or compressed, 16-60  $\mu$  radially, 40-60  $\mu$  tangentially, each bearing 1-2 cuneate-cylindrical stalk cells, 18-25  $\mu$  tall, upper end simple or slightly furcate, 12-18  $\mu$  in diameter, lower 8-12  $\mu$ ; terminal cells ovate or clavate, 22-36  $\mu$  tall, 18-25  $\mu$  in diameter, loosely arranged, appearing subglobose on the surface; extended assimilatory filaments 0.5-1.5 mm. long; tumid basal cells 1-2, size 50-70  $\mu$  long, 24-40  $\mu$  in diameter; shaft cells 18-20  $\mu$  in diameter, 2-4 times as long as broad.

The distinction between the Pacific *G. arborea* and the West Indian *G. frutescens* is so trivial that I often doubted the value of separation. In the Philippine collection plants under *Bartlett 15009A* agree very closely with Kjellman's description of *G. frutescens*, whereas his plants under 14608, collected from the same locality but earlier in the season, showed vigorous growth and arborescent habit. At first I was tempted to call the former *G. frutescens* and the latter *G. arborea*, but since they all came from the same locality the minor external differences were treated as seasonal variations, and the plants were considered identical.

*Type locality.* — Australia.

*Type specimen.* — In J. C. Agardh's herbarium, under the name *Galaxaura marginata*.

*Specimens studied.* — PHILIPPINE ISLANDS: Dalupiri Island, Babuyan, *Bartlett 14608*, July 17; *15009A*, Oct. 5, 1935.

*Further distribution.* — Japan, Hongkong, Hainan Island, Australia, Hawaiian Islands.

*Galaxaura apiculata* Kjellman. — Pl. V,  
Figs. 13-19; Pl. IX, Fig. 1

Kjellman, 1900, pp. 74-75, pl. 12, figs. 13-26, p. 20, fig. 36; Tanaka, 1936, pp. 162-163, figs. 26-27, pl. 41, fig. 2.

Plants 8-9 cm. high (basal attachment not seen); branches flabellate, flattened, decompound-furcate, angles obtuse or round, often subtending  $70^{\circ}$ - $90^{\circ}$ ; segments 5-12 mm. long, margins thickened; proliferations few, their bases encircled by tufts of extended assimilatory filaments; medullary filaments 8-12  $\mu$ , rarely 16-20  $\mu$  in diameter; cortical parenchyma monostromatic, cells large, subglobose or compressed, each bearing 1-2 cylindrical or cuneate-cylindrical stalk cells, 18-25  $\mu$  tall; terminal cells subglobose, oval or obpyriform, 40-50  $\mu$  tall, 40-44  $\mu$  in diameter, distal end wall apiculate; apiculi 2  $\mu$  tall, in older cells often attaining a sublateral position, thus not easily seen; extended assimilatory filaments 0.5-1.5 mm. long, 25-40  $\mu$  broad; shaft 12-15  $\mu$  in diameter, cells 3-4 times as long as the diameter.

The species is characterized by having mucronate terminal cells — a specific character established by Kjellman to distinguish the Japanese plant from *G. marginata* of the West Indies. This characteristic, however, has been questioned by Børgesen, who says that the numerous specimens he collected in the Danish West Indies agree in all essentials with Kjellman's description of the Pacific plants, except that the terminal cells of the West Indian plants end commonly, but not always, in a short apiculus. My observation of the West Indian *G. marginata* did not quite agree with Børgesen's, for in only two specimens, one from Bermuda, the other from the West Indies, did I detect a few sporadic mucronate cells, with apiculi not so tall as those of the Philippine and the Tonga plants.

The terminal cells of the Tonga plant have a slightly smaller diameter than those of the Philippine plants, but since both specimens show apiculate terminal cells they are treated as identical.

Since both specimens lack basal attachment, it is impossible to tell whether the plants are arborescent or frutescent. The Philippine plants were recorded as "cast up by waves," so that it is quite possible that they represent only parts of a plant broken off from the basal attachment, and might easily be caulescent, and thus agree in habit with Kjellman's *G. apiculata* from Japan.

*Type locality.* — Pacific Ocean near Japan.

*Specimens studied.* — PHILIPPINES: Puerto Galera Bay, Mindoro Island, Bartlett 13782, May 12-17, 1935; TONGA: Mukualofa, Brooks in herb. Taylor, 25494, Aug. 27, 1931.

*Further distribution.* — Japan.

*Galaxaura spathulata* Kjellman. — Pl. V,  
Figs. 6-9; Pl. XI, Fig. 2

Kjellman, 1900, p. 74, pl. 12, figs. 5-12, pl. 20, fig. 35.

Plants to 18 cm. or more high, subcaulescent; caudex villous, warty, 3-4 cm. long, 4-6 mm. thick; branching dichotomous, angles acute, branches flattened, carnose- or subcoriaceous-membranous, continuous, rarely proliferous; segments 0.5-1.5 cm. long, upper end 1.5-3.0 mm., the lower 0.5-1.5 mm. in diameter, inconspicuously transversely striate, margins slightly thickened, tomentose when injured; apex of branches round, spathulate, or subfalcate; medullary filaments in the caudex 8-32  $\mu$  in diameter, peripheral filaments assimilatory or rhizoidal, with well-developed tumid basal cells forming cortical tissue; cortical parenchyma tissue 1-3-stromatic, 60-80  $\mu$  thick, the innermost cells largest, globose or compressed, 24-60  $\mu$  tall, 60-80  $\mu$  broad, the outer cells ovate or obpyriform, each bearing 1-2 cuneate-cylindrical, simple or once-furcate stalk cells, 20-32  $\mu$  long; terminal cells variable, subglobose, oval, or obpyriform, 30-44  $\mu$  tall, 25-30  $\mu$  in diameter, much crowded, in surface view angular; extended assimilatory filaments 1.0-1.5 mm. long, with one or two tumid basal cells, 70-90  $\mu$  long; 30-40  $\mu$  in diameter; shaft 20  $\mu$  in diameter, cells 2-4 times as long as thick; marginal tomentum similar to young extended assimilatory filaments, cells shorter, 1-2 times as long as the diameter.

In habit these plants from Ecuador resemble in some respect each of the Pacific Arboreae described by Kjellman, and thus difficulty is encountered in identifying the species. Kjellman's specific recognition of these plants was primarily based on their general growth habit and the superficial forms of the branch tips — characters which may not be reliable for specific separation unless supported by structural features.

Perhaps I should call these Ecuadorian plants *G. arborea* instead of *G. spathulata* because they resemble both species in certain respects, and if future study should prove the species identical the former name would be valid because of priority. However, since the plants are tall like those of *G. spathulata* and since in habit they do not resemble *G. arborea* of the Philippine Islands, they are tentatively assigned to *G. spathulata*.

The collection includes a sexual plant which is likewise tall and



arborescent, resembling the asexual plant of *G. spathulata*. It may represent the sexual phase of *G. spathulata*, but is tentatively ascribed to the section *Angustifrones* because of its smooth branches, whose epidermal cells are free from spinulose outgrowths.

*Type locality*. — Freemanntle, Australia.

*Type specimen*. — In Areschoug's herbarium, under the name *Microthoë marginata* Decaisne.

*Specimens studied*. — ECUADOR: Isabela Island, Taylor 34-164, Jan. 13, 1934; Santa Maria Island, Galápagos Islands, Taylor 34-246, Jan. 17-18, 1934.

*Further distribution*. — Australia.

#### SUPPLEMENTARY NOTE

The species *Galaxaura barbata* is closely related to *G. paschalis* Børgesen from Easter Island. (See F. Børgesen, "Marine Algae from Easter Island," in C. Skottsberg, *The Natural History of Juan Fernandez and Easter Island*, Vol. II, Part III, pp. 247-309, 50 figs. Uppsala, 1924; preprint dated 1920 on back cover.) Børgesen's species is likewise characterized by having cylindrical branches with well-developed whorls of hairs, but *G. barbata* differs from it in several respects. The terminal cells of the short assimilatory filaments of *G. barbata* are ovate or subglobose, and the cortical cells are well developed, forming a monostromatic layer of parenchymatous tissue, whereas the terminal cells in *G. paschalis* are two or three times as long as wide, and the cortical cells are either poorly developed or undifferentiated. The tumid basal cells of the extended assimilatory filaments in *G. barbata* are very large and prominent, and the corresponding cells as described by Børgesen are little differentiated. Unfortunately, Skottsberg's work escaped my notice until the present paper was in type, since Børgesen's species had not been referred to in the sources usually consulted. To judge from the description only (for I have not seen material from Easter Island), *G. paschalis* would key out to *G. barbata*, from which it should be easily distinguished by the contrasting characteristics here pointed out.

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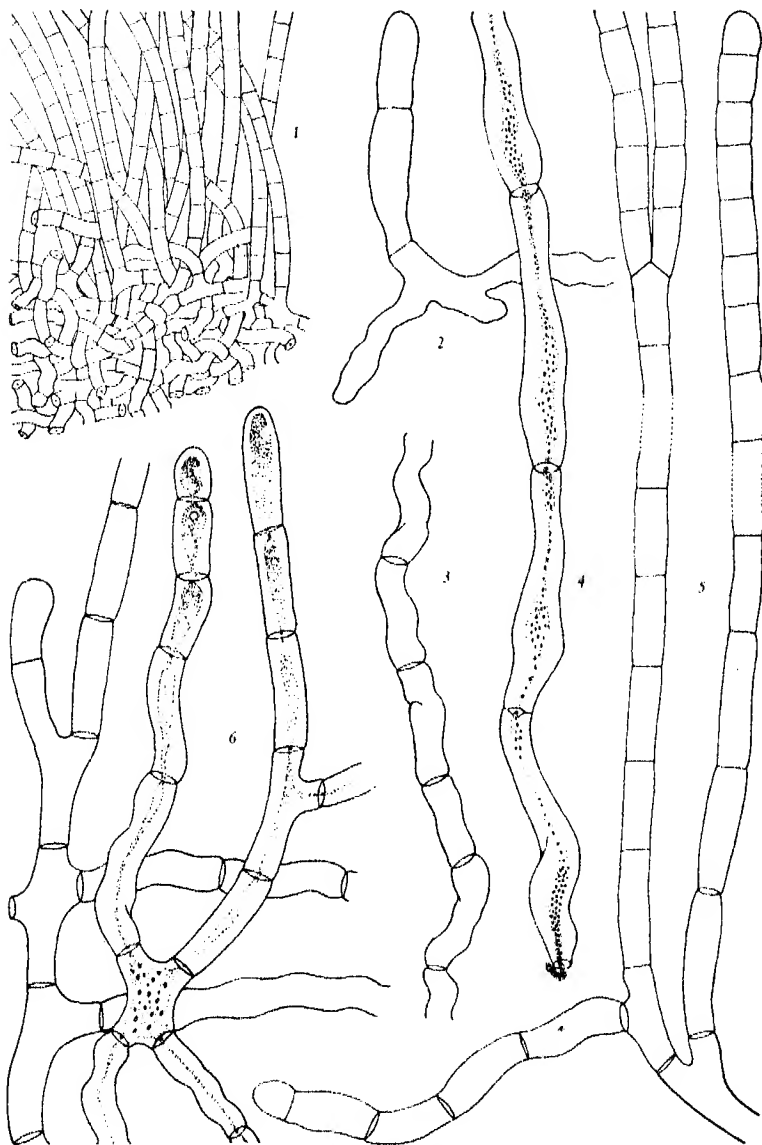
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## EXPLANATION OF PLATE I

### *Galaxaura filamentosa*

- FIG. 1. Section of portion of thallus.  $\times 140$   
FIG. 2. Young extended assimilatory filament.  $\times 225$   
FIGS. 3-4. Medullary filaments containing starch grains.  $\times 225$   
FIG. 5. Mature extended assimilatory filaments, showing branching.  $\times 225$   
FIG. 6. Extended assimilatory filaments with undifferentiated or poorly developed supporting cells.  $\times 225$

*Galaxaura filamentosa*

## EXPLANATION OF PLATE II

### *Galaxaura subverticillata*

FIG. 1. Section of portion of thallus.  $\times 195$

### *G. fasciculata*

FIG. 2. Section of portion of thallus, showing fasciculate short assimilatory filaments.  $\times 195$

### *G. ramulosa*

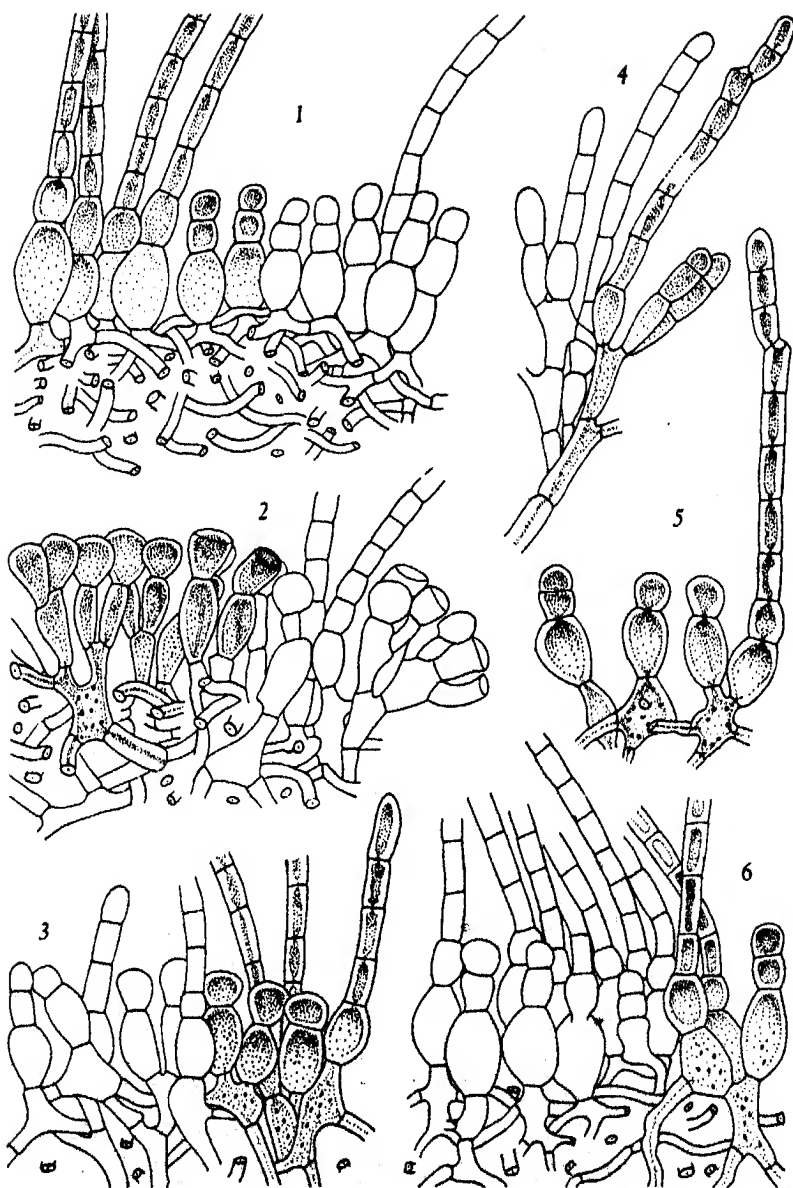
FIG. 3. Section of portion of thallus.  $\times 195$

FIG. 4. Various stages of extended assimilatory filaments.  $\times 195$

FIG. 5. Short and extended assimilatory filaments borne separately or by a common supporting cell.  $\times 195$

### *G. subfruticulosa*

FIG. 6. Section of portion of thallus.  $\times 195$

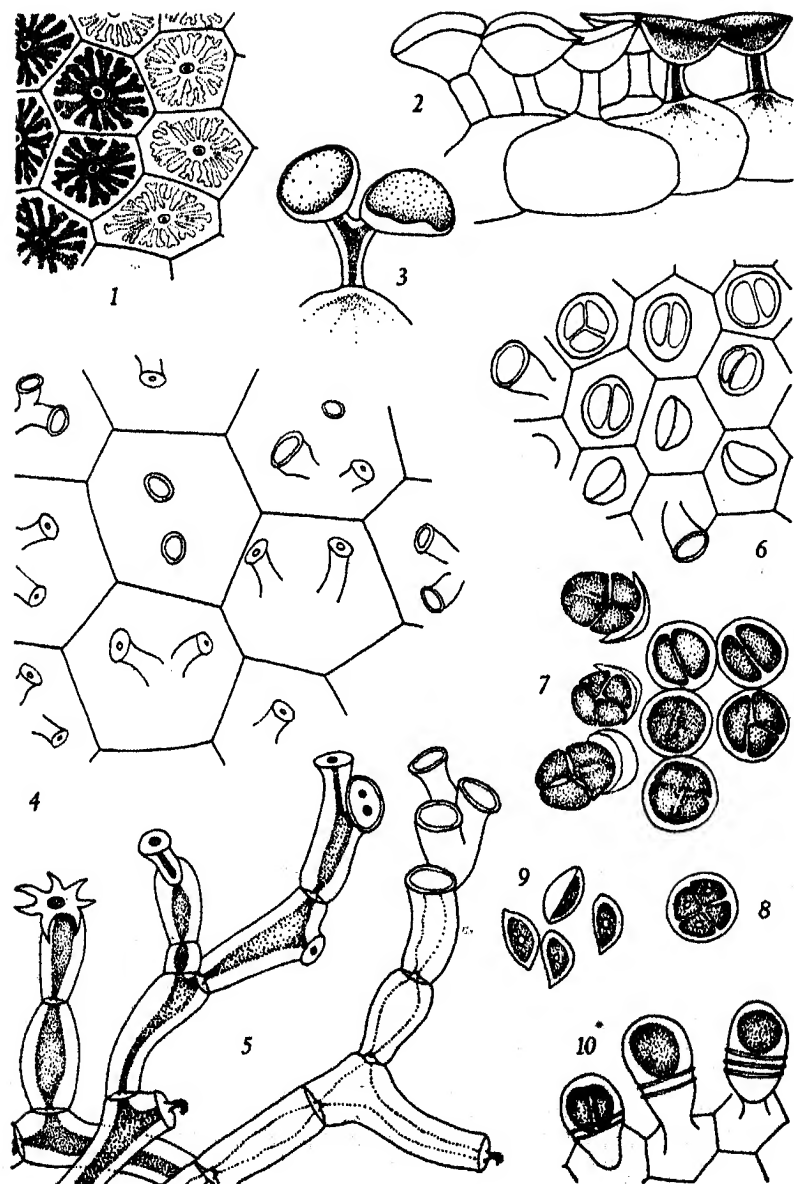


*Galaxaura* species

## EXPLANATION OF PLATE III

### *Galaxaura robusta*

- FIG. 1. Surface of thallus, showing terminal cells with large stellate chromatophores.  $\times 340$
- FIG. 2. Section of thallus, showing assimilators and cortical cells.  $\times 340$
- FIG. 3. Single cortical cell, with bifurcate stalk cell bearing two terminal cells.  $\times 340$
- FIG. 4. Cortical cells, exterior view, showing stalk cells after terminal cells become detached.  $\times 340$
- FIG. 5. Medullary filaments near periphery bearing cortical cells at the distal ends.  $\times 340$
- FIG. 6. Sorus, surface view.  $\times 340$
- FIG. 7. Sporangia, showing cleavage of spore mother cells.  $\times 340$
- FIG. 8. Mature sporangium with tetrads.  $\times 340$
- FIG. 9. Mature spores.  $\times 340$
- FIG. 10. Sporangia, lateral view, showing regeneration within old sporangia walls.  $\times 340$

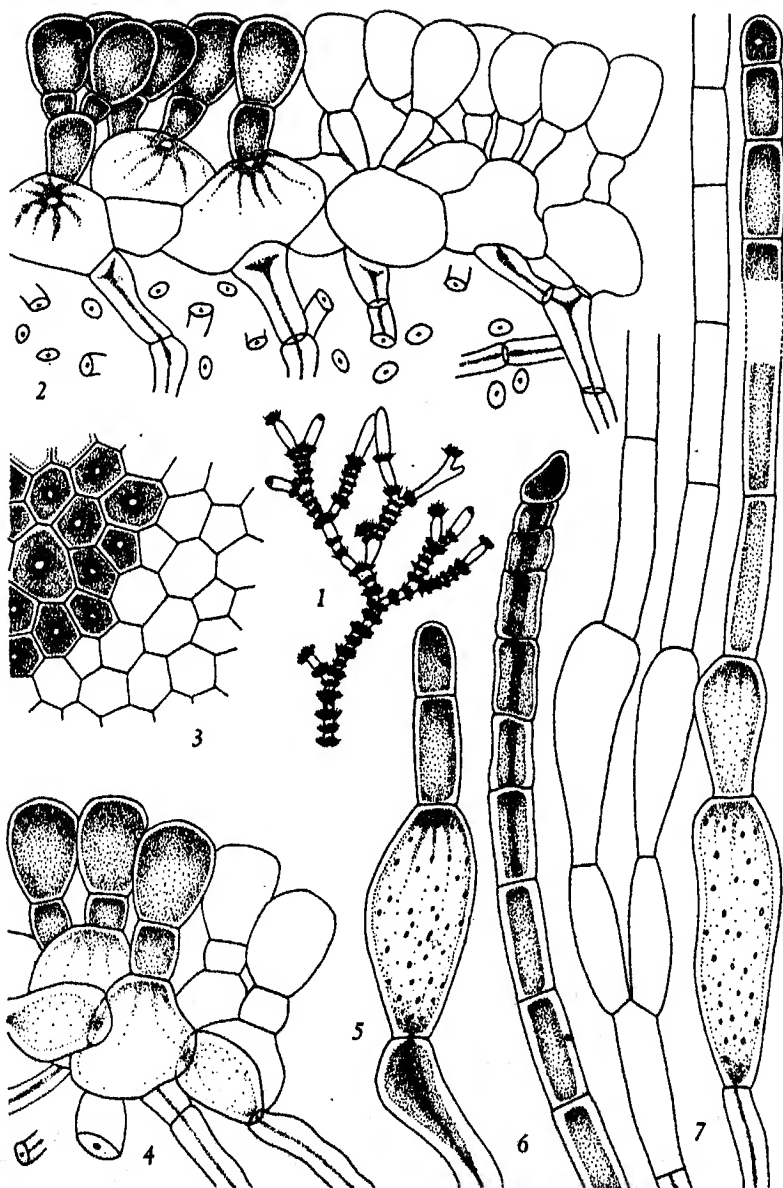
*Galazaura robusta*



## EXPLANATION OF PLATE IV

### *Galaxaura barbata*

- FIG. 1. Habit of portion of plant, showing barbate extended assimilatory filaments.  $\times 1.5$
- FIG. 2. Section of portion of thallus.  $\times 340$
- FIG. 3. Surface of thallus.  $\times 340$
- FIG. 4. Section of portion of young thallus.  $\times 340$
- FIG. 5. Young extended assimilatory filament.  $\times 340$
- FIG. 6. Apical part of extended assimilatory filament.  $\times 340$
- FIG. 7. Basal part of extended assimilatory filament, showing large tumid basal cells.  $\times 340$

*Galaxaura barbata*

## EXPLANATION OF PLATE V

### *Galaxaura arborea*

FIG. 1-2. Section of portion of thallus, showing cortical cells and assimilators.  $\times 225$

FIG. 3. Interior surface view of cortical cells, showing connection with medullary filaments.  $\times 150$

FIG. 4. Young assimilators at apical parts of branches.  $\times 225$

FIG. 5. Extended assimilatory filaments at base of proliferations.  $\times 160$

### *G. stupicaulis*

FIG. 6-8. Young assimilators, showing connections with medullary filaments.  $\times 225$

FIG. 9. Section of portion of thallus.  $\times 225$

### *G. spathulata*

FIG. 10. Short assimilators.  $\times 225$

FIG. 11-12. Section of portion of thallus, showing cortical tissue and assimilators.  $\times 225$

### *G. apiculata*

FIG. 13. Terminal cells without apiculi.  $\times 225$

FIG. 14. Young assimilators, with apiculate terminal cells.  $\times 225$

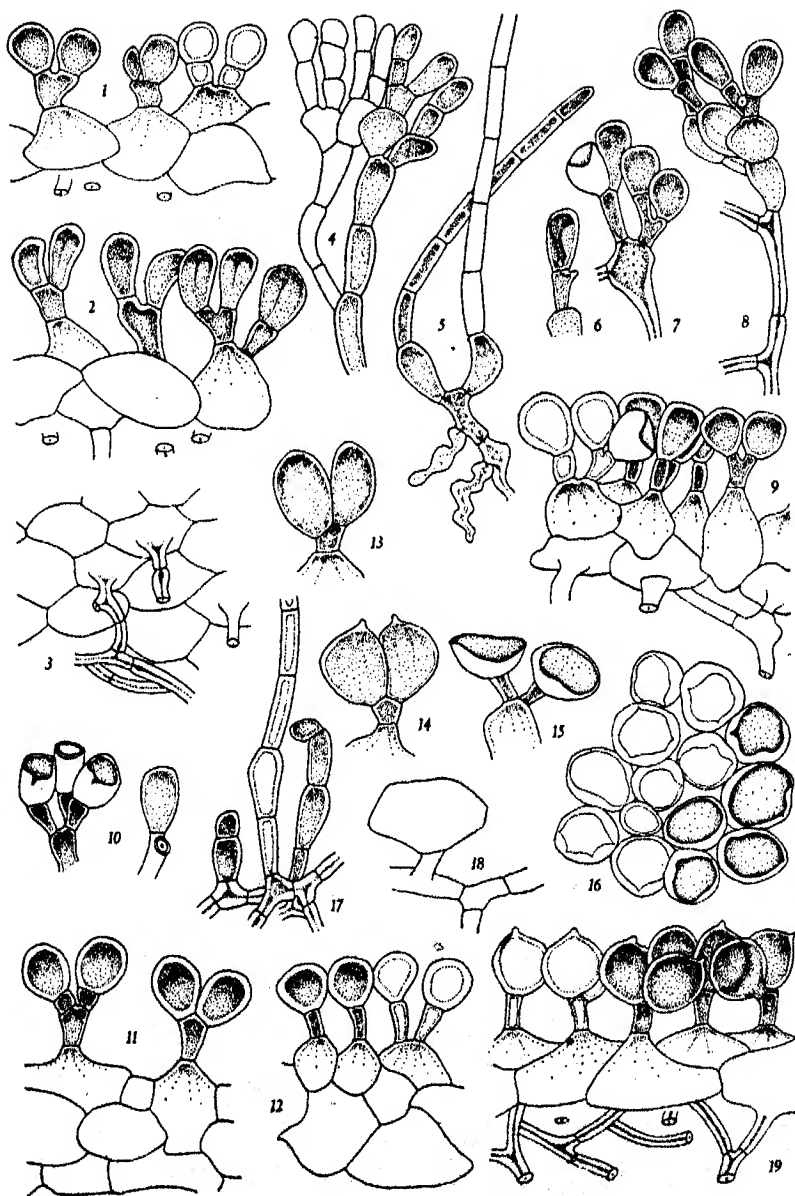
FIG. 15. Old assimilators.  $\times 225$

FIG. 16. Assimilators, surface view.  $\times 225$

FIG. 17. Extended assimilatory filaments from base of proliferations.  $\times 150$

FIG. 18. Inner cortical cell in connection with medullary filament.  $\times 225$

FIG. 19. Section of portion of thallus.  $\times 225$

*Galaxaura* species

### EXPLANATION OF PLATE VI

FIG. 1. *Galaxaura filamentosa*, sp. nov.; type specimen.  $\times 1$

FIG. 2. *G. barbata*, sp. nov.; type specimen.  $\times 1.5$



*Galaxaura* species

## EXPLANATION OF PLATE VII

FIG. 1. *Galazaura ramulosa*; Taylor no. 34-505, Jicarita Island, Panama.  $\times 1.4$

FIG. 2. *G. subverticillata*; Villaflores no. 7A, Mindoro, Philippines.  $\times 2.2$



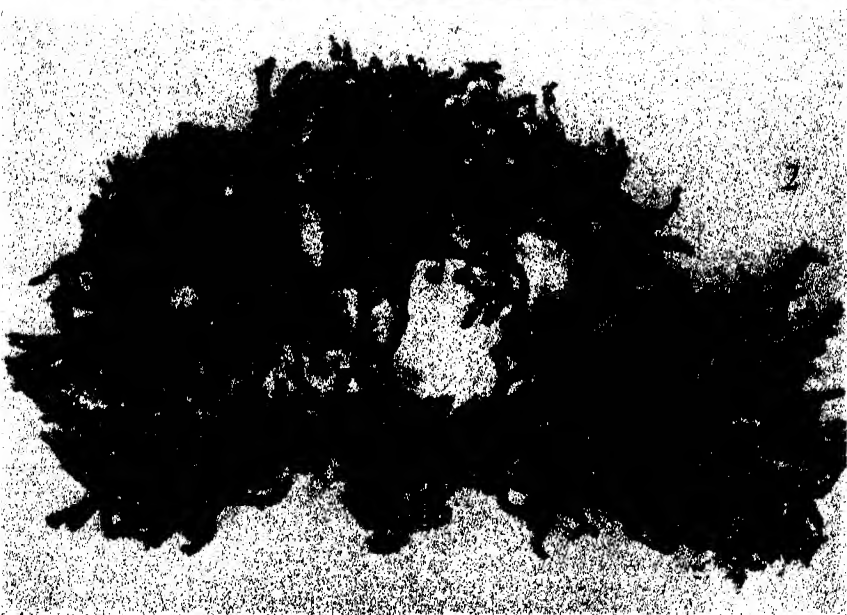
*Galaxaura* species



### EXPLANATION OF PLATE VIII

FIG. 1. *Galaxaura fasciculata*; Kostermans no. 429, Java.  $\times 1.2$

FIG. 2. *G. subfruticulosa*, sp. nov.; type specimen.  $\times 1.3$

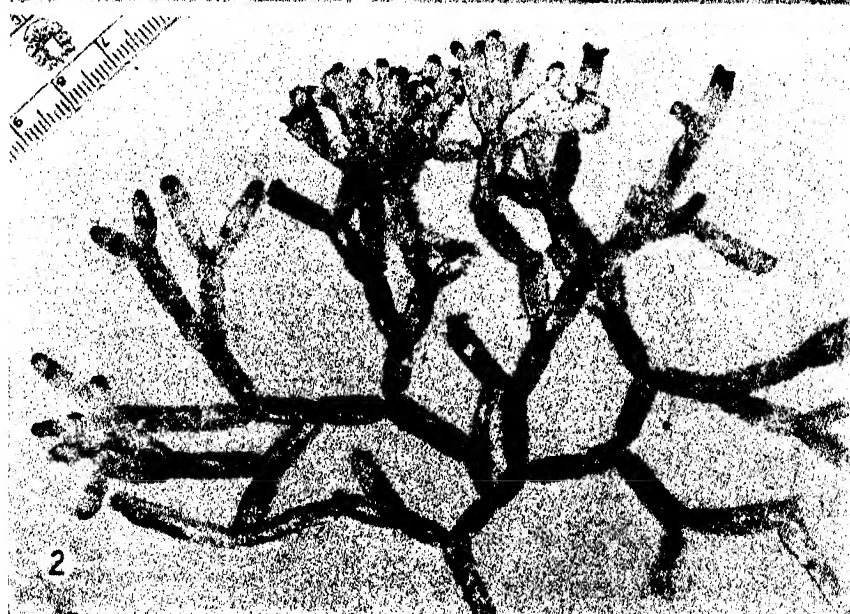
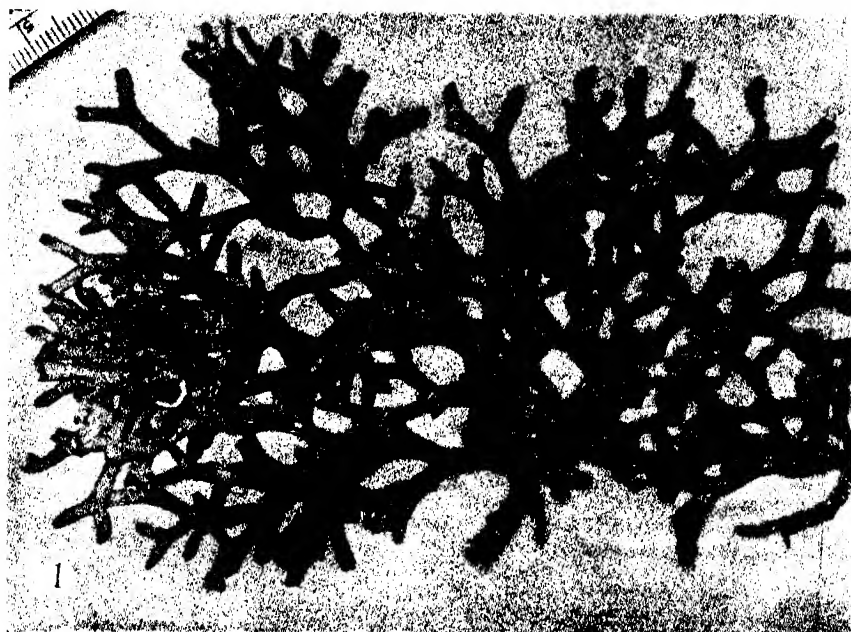


*Galaxaura* species

### EXPLANATION OF PLATE IX

FIG. 1. *Galaxaura apiculata*; Brooks in Taylor's herb. no. 20494, Mukualofa, Tonga.  $\times 0.9$

FIG. 2. *G. robusta*; Brooks in Taylor's herb. no. 20444, Mukualofa, Tonga.  $\times 0.8$



*Galaxaura* species

## EXPLANATION OF PLATE X

FIG. 1. *Galazaura arborea*; Bartlett no. 15009A, Dalupiri Island, Philippines.  
× 1

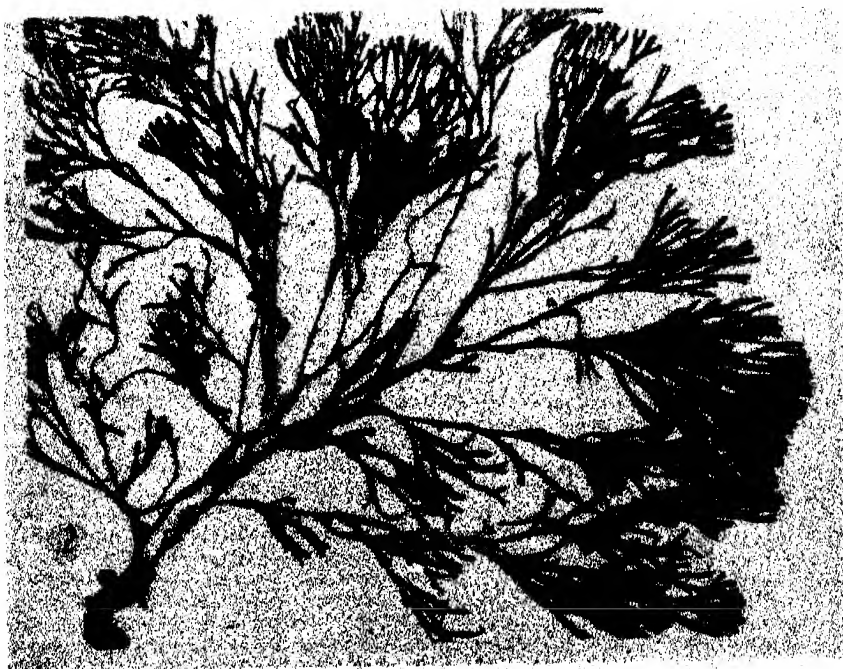
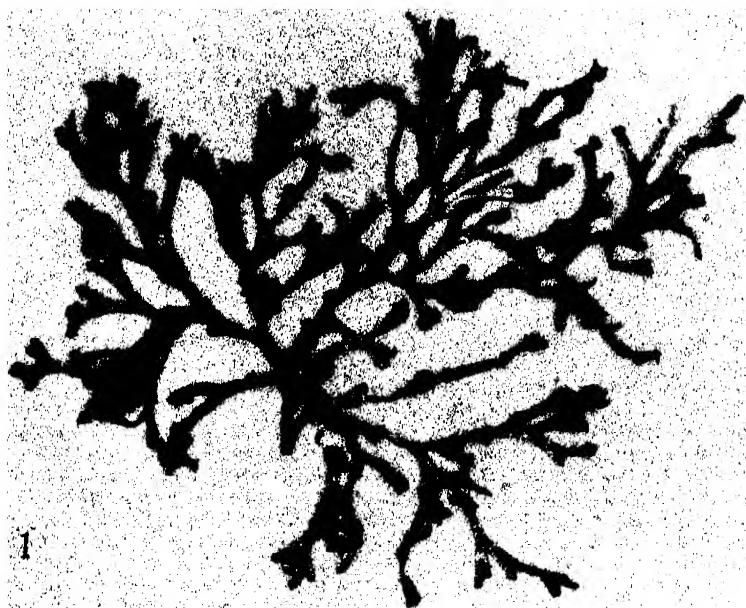
FIG. 2. *G. arborea*; Bartlett no. 14608, Dalupiri Island, Philippines. × 1.1



*Galaxaura* species

## EXPLANATION OF PLATE XI

- FIG. 1. *Galaxaura stupicaulis*; Taylor no. 39-90A, Golfo Dulce, Costa Rica.  
× 1.5
- FIG. 2. *G. spathulata*; Taylor no. 34-164, Isabela Island, Galápagos Islands.  
× 0.5



*Galaxaura* species





## NOTES ON THE MICHIGAN FLORA. IX \*

OLIVER A. FARWELL †

THE present addition to the series of papers on Michigan flora deals with the extension of ranges, new stations, and the naming of some forms that are worthy of being put on record systematically.

### LIST OF SPECIES

**WOODSIA ALPINA** (Bolton) S. F. Gray. — Two more stations have been found for this rare fern, making four in all on the Keweenaw Peninsula. Keweenaw Co.: Esrey Park, no. 12222½, Sept. 25, 1939; Lac La Belle, no. 12097, Aug. 16, 1939.

**WOODSIA CATHCARTIANA** B. L. Robinson. — Also rare on the Keweenaw Peninsula. In crevices of rocks. Keweenaw Co.: West Bluff, no. 12153, Sept. 5, 1939; Lookout Mt., no. 12395, July 3, 1940, and no. 12697, Aug. 27, 1940.

**WOODSIA OREGANA** D. C. E. — In crevices of rocks, on faces of bluffs. Lac La Belle, Keweenaw Co., nos. 12096, 12097½, Aug. 16, 1939.

**POTAMOGETON PRAELONGUM** Wulf. — The first time I have ever found it, though it is said to occur throughout the state. In Lake Manganese, Keweenaw Co., no. 12581, Aug. 6, 1940.

**POTAMOGETON CAPILLACEUM** Poir. — This species will take the place of *P. diversifolium*, now excluded from Michigan, unless on reëxamination Lyon's material proves to contain it.

**POTAMOGETON PORCATUS** Muhl. (*P. Spirillus* Tuckerm.). — Arthur Bennett, *Journal of Botany*, 28 (1890): 297, states that a specimen from Muhlenberg, labeled by himself as his *P. porcatum*, is in the herbarium of Sir J. E. Smith. Since species are now typified by specimens, this plant directly from Muhlenberg must stand as the type of his species. Bennett says it is *P. Spirillus*.

\* All the previous papers in this series are to be found in the following Michigan Academy publications: *Reports*, 20 (1918): 161-195; 21 (1919): 345-371; 22 (1920): 177-185; *Papers*, 1 (1921): 85-100; 2 (1922): 11-46; 3 (1923): 87-109; 23 (1937): 123-134; 26 (1940): 3-20.

† Died September 18, 1944.

- Tuckerm.; hence it must supersede Tuckerman's name. In ponds at North Cliff, Keweenaw Co., no. 458, Aug. 20, 1886.
- CALAMAGROSTIS NEGLECTA* (Ehrh.) Gaertn. — This species of reed grass is said to be rare in Michigan. It is listed by Beal in *Michigan Flora* (1904) and by Hitchcock in his *Manual of Grasses* (1935); but Stebbins excludes Michigan from the range of the species in his "Revision of Some North American Species of *Calamagrostis*," *Rhodora*, 32 (1930): 53-56. Among the conglomerate on shores of Lake Superior east of Eagle Harbor, Keweenaw Co., no. 12564, Aug. 6, 1940.
- DESCHAMPSIA CAESPITOSA* (L.) Beauv. var. *GLAUCA* (Hartm.) Hartm. — This variety is smaller than the species in all its parts and has involute leaves. On rocky shores. Rare. Near Eagle Harbor, Keweenaw Co., no. 12534, July 30, 1940.
- DESCHAMPSIA FLEXUOSA* (L.) Trin. — In rocky woods, sandy places, and open ground; in dry places, whereas the preceding species is one of wet places. Very abundant. Cliff Mine, Keweenaw Co., no. 12426, July 8, 1940. Little Traverse Bay, Houghton Co., no. 12028, July 28, 1939.
- POA PALUDIGERA* Fern. & Wieg. — Near springs and in wet woods. Keweenaw Co.: Gay, no. 12061, July 28, 1939; Cliff Mine, no. 12427, July 8, 1940.
- NARDUS STRICTA* L. — Mat grass. A second station in Michigan has been found for this European grass. Since it covers a rather large stretch of lowland near the highway and comprises a colony of several hundred stools, it would appear to have been here for a number of years. Lake Linden, Houghton Co., no. 12783, Nov. 3, 1940.
- CAREX SICCATA* Dew. — In dry fields and on sandy hills. West Bluff, Keweenaw Co., no. 12374, June 28, 1940. Previously collected as follows: Ypsilanti, Washtenaw Co., no. 5457, May 30, 1920; Oakland Co.: Orion, no. 987, May 30, 1895; Parkedale Farm, no. 2656, June 9, 1912; Bloomfield Hills, no. 5225, June 5, 1919; due west of Bloomfield Hills, no. 7911, June 1, 1927.
- CAREX SCIRPOIDES* Schk. var. *CAPILLACEA* (L. H. B.) Fernald (*C. Howei* K. K. M.). — Keweenaw Co.: in a peat bog near Eagle Harbor, no. 12511, July 30, 1940; in rich woods at Copper Harbor, no. 12600, Aug. 6, 1940.
- CAREX LARICINA* K. K. M. — In peat bogs and swampy shores of

lakes. Shores of Rice Lake, Houghton Co., no. 12410, July 8, 1940. Keweenaw Co.: Meadow Mine, no. 12505, July 30, 1940; Eagle Harbor, no. 12507, July 30, 1940.

*CAREX FESTUCACEA* Schk. — In the *North America Flora Mackenzie* does not give Michigan in the geographical distribution of this species. He made the determination of my collection, but did not see it in time to include Michigan in its range. Temperance, Monroe Co., no. 8004, July 13, 1927.

*CAREX MOLESTA* K. K. M. — Identifications by Mackenzie. A segregate from *C. brevior* (Dew.) K. K. M. Rockwood, Wayne Co., no. 4940, June 16, 1918. Monroe Co.: Dundee, no. 5294, July 15, 1918; La Salle, no. 5817, June 2, 1921; Stony Creek, no. 5823, June 9, 1921; South Rockwood, no. 5861, June 14, 1921, and no. 5919, July 12, 1921.

*CAREX BREVIOR* (Dew.) K. K. M. — Open dry soil or sand. Harris, Oakland Co., no. 5081, July 13, 1918. Woodville, Newaygo Co., no. 5958, Aug. 4, 1921; near Lake Glazon, Keweenaw Co., no. 11801, Aug. 29, 1938.

Var. *PSEUDOFESTUCACEA* O. A. F. — In moist ground. Algonac, St. Clair Co., no. 5500a, June 20, 1920.

*CAREX BICKNELLII* Britt. — In dry soil. Oakland Co.: Bloomfield Hills, no. 5225, June 5, 1919; Royal Oak, no. 5578, Aug. 12, 1920; Goodison, no. 7676, Sept. 30, 1925. Ypsilanti, Washtenaw Co., no. 5457a, May 30, 1920.

*CAREX BACKII* Boott. — In dry woods on bluffs; very scarce. Cliff Mine, Keweenaw Co., no. 12431, July 8, 1940.

*CAREX CAPILLARIS* L. — On bluffs; rare. Cliff Mine, Keweenaw Co., no. 1824½, Aug. 4 to 11, 1904.

Var. *ELONGATA* Olney. — Taller with remote spikes. Rare. Mackinac Island, Mackinac Co., no. 967, June 20, 1895. Among conglomerate on shores east of Eagle Harbor, Keweenaw Co., no. 12568, Aug. 6, 1940.

*JUNCUS INFLEXUS* L. — Very abundant along the highway near Hancock, where it was discovered in 1936 by F. J. Hermann, who says that the only other station for this European species in North America is in New York. Superficially it looks like *J. Balticus*, but the inflorescence is more condensed, and the plant is densely caespitose and glaucous. Quincy Hill, Houghton Co., no. 12735, Sept. 17, 1940.

**JUNCUS TENUIS** Willd. var. **BILLINGTONII** O. A. F. — In this variety the inflorescence is reduced to an umbel of two to five subequal rays, each terminated by a single flower; in appearance it is somewhat like that of *Juncoides carolinæ* (S. Wats.) O. K. In moist soil near Lake Linden, Houghton Co., no. 11789, Aug. 21, 1938.

Var. **UNIFLORUS** O. A. F. — In this variety the inflorescence is reduced to a single sessile flower. Lake Linden, Houghton Co., no. 11790, Aug. 21, 1938.

**JUNCUS CANADENSIS** J. Gay. var. **paradoxa**, var. nov. — *Inflorescentia omnino prolifera*. The inflorescence is reduced to proliferous buds. Occasional, on shores of Rice Lake, Houghton Co., no. 12726, Sept. 3, 1940.

**JUNCUS BRACHYCEPHALUS** (Engelm.) Buch. — Beal, in *Michigan Flora*, gives only four citations, all for the southern part of the Lower Peninsula. It is found occasionally in the Copper Country. Houghton Co.: shores of Torch Lake, no. 11476, Aug. 11, 1936; Laurium, no. 11485, Aug. 14, 1936; on the Quincy Hill, no. 12756, Oct. 8, 1940. Gay, Keweenaw Co., no. 12061, July 28, 1939.

**UNIFOLIUM BIFOLIUM** (L.) Greene. — In the Copper Country this species is called "wild lily of the valley." The typical pubescent variety was found during 1940. This collection extends the range throughout the state. Keweenaw Co.: shores of Lake Bailey, no. 12330, June 23, 1940; shores of Lake Superior near Devil's Washtub, no. 12346, June 23, 1940.

Var. **ovale** (Ph.) O. A. F. subvar. **hirtellum**, subvar. nov. — *Planta pilosa*. The whole plant is more or less pubescent. In the Copper Country this variety with broadly oval leaves and overlapping basal lobes is easily distinguishable from the narrow-leaved varieties. Keweenaw Co.: shores of Lake Bailey, no. 12331, June 23, 1940; shores of Lake Superior, near the Devil's Washtub, no. 12347, June 23, 1940.

**RANUNCULUS FLAMMULA** L. var. **FILIFORMIS** (Mx.) Hook. — A slender plant with filiform stems and leaves creeping in mud of lake shores. Rice Lake, Houghton Co., no. 12722, Sept. 3, 1940. Lake Manganese, Keweenaw Co., no. 12588, Aug. 6, 1940.

**CAPNOIDES AUREUM** (Willd.) O. K. — A low diffusely branching herb with many-flowered racemes of golden-yellow flowers. Along

roadsides; rare. Canal, Houghton Co., no. 9625, May 20, 1934; Esrey Park, Keweenaw Co., no. 12354, June 23, 1940.

*SAXIFRAGA VIRGINIENSIS* Mx. — This species was seen and collected in 1940, the first time since 1883. *Gray's New Manual* (1908), p. 446, describes the leaves as obovate or oval-spatulate and the follicles as purplish; the *North American Flora*, 22 (1905): 141, as ovate, oval, or oblong and the follicles as mainly green. The latter I take as the type. Exposed rocks and hillsides. Keweenaw Co.: Cliff Mine, no. 22, June 18, 1883; Lookout Mt., no. 12704½, Aug. 27, 1940. The species described in *Gray's New Manual* may be known by the following varietal name.

Var. *cuneata*, var. nov. — *Foliis cuneatis-obovatis vel spatulatis*. Leaf cuneately obovate or spatulate. Exposed rocks. Lookout Range, Keweenaw Co., no. 12254, June 13, 1940.

*FRAGARIA GRANDIFLORA* Ehrh. — Found in open woods near Lake Superior. Evidently an escape from cultivation. Near Cat Harbor, Keweenaw Co., no. 12457, July 16, 1940.

*ROSA BLANDA* Ait. var. *HERMANNI* Erlan. — Swampy grounds. Near Eagle Harbor, Keweenaw Co., no. 11866, Oct. 6, 1938. Near Bear Lake, Houghton Co., 12743, Sept. 17, 1940.

*PRIMULA MISTASSINICA* Mx. — On wet rocky shores. The *P. farinosa* of Beal's *Michigan Flora* is the *P. intercedens* Fernald, *Rhodora*, 30 (1928): 86, already reported upon. The *P. mistassinica* is divided, and a new variety is established by Fernald, *op. cit.*, p. 91. The type is more frequent than the variety. Keweenaw Co.: near the Devil's Washtub, no. 12345, June 23, 1940; Sand Bay, no. 12448, July 16, 1940.

Var. *noveboracensis* Fern. — Sand Bay, Keweenaw Co., no. 12440, July 16, 1940.

*GALEOPSIS TETRAHIT* L. forma *alba*, forma nov. — *Floribus albis vel incarnatis-variegatis*. The corolla is white or variegated with pink. In the typical variety of the species the flowers are purplish. In waste places and in moist open woods. Houghton Co.: shores of Lake Roland, no. 10238, Aug. 13, 1934; Lake Linden, no. 11681, Aug. 5, 1937, and no. 12616, Aug. 11, 1940. Keweenaw Co.: Bete Grise Bay, no. 12107, Aug. 16, 1939; Eagle Harbor, no. 12677, Aug. 20, 1940.

*MENTHA PIPERITA* L. var. *SUBHIRSUTA* Benth. — This variety has the underside of the leaves and the stems more or less pubescent. Eagle Harbor, Keweenaw Co., no. 12668, Aug. 20, 1940.

**COLLINSIA PARVIFLORA** Dougl. — Blue-eyed Mary. A large plant much and diffusely branched, four to nine inches high. On exposed rocky bluffs. Keweenaw Co.: West Bluff, no. 11319, July 14, 1936; Mt. Brockway, no. 11966, June 23, 1939; Lookout Mt., no. 12280, June 13, 1940.

Var. **simplex**, var. nov. — *Plantis humilioribus simplicibus*. Similar to the species but low, usually one or two inches high, rarely up to three and one-half inches, and unbranched. Similar situations. Keweenaw Co.: on dry hills near Cliff Mine, no. 322, Aug. 16, 1885; Lookout Mt., no. 12266, June 13, 1940.

**PLANTAGO LANCEOLATA** L. var. **IRRIGUA** Dcne. — Similar in appearance to the next species, but the scapes are shallowly and irregularly ten- to twelve-striate or channeled. L'Anse, Baraga Co., no. 10885, July 7, 1935. Lake Linden, Houghton Co., no. 10962, Aug. 4, 1935.

**PLANTAGO ALTISSIMA** L. — Scapes up to three feet in height, deeply five-channeled, alternating with five sharply acute angles. In fields, Lac La Belle, Keweenaw Co., no. 12469, July 23, 1940.

**CAMPANULA ULIGINOSA** Rydb. — Blue marsh bellflower. Not in Beal's *Michigan Flora*; to the best of my knowledge this is the first report of its occurrence in Michigan. In wet meadows. Keweenaw Co.: Meadow Mine, no. 12495, July 30, 1940; Cat Harbor, no. 12608, Aug. 8, 1940.

**SOLIDAGO HISPIDA** Muhl. var. **TONSA** Fern. — This variety is found on dry, exposed soil. Original range was given as Newfoundland, Quebec, and New Brunswick. It is now found in Michigan; on Lookout Mt., Keweenaw Co., nos. 12706 and 12710, Aug. 27, 1940.

**SOLIDAGO LONGIPETIOLATA** Mack. & Bush. — Along roadsides in copses. Extends the range eastward from Minnesota. Quincy Hill, Houghton Co., no. 12739, Sept. 17, 1940.

**IVA XANTHIFOLIA** Nutt. — Along roadsides; dwarf plants under a foot in height. Quincy Hill, Houghton Co., no. 12758, Oct. 8, 1940.

LAKE LINDEN, HOUGHTON COUNTY  
MICHIGAN

## ADDITIONS TO THE FLORA OF MICHIGAN. V

CLARENCE R. HANES

ONE of the collections listed in the present paper was by H. R. Becker of Climax; another, by F. W. Rapp, of Vicksburg. The rest were made chiefly in 1942 and 1943 by Mrs. Florence N. Hanes and the writer. All plants are from Kalamazoo County, Michigan. Specimens of most of these have been deposited in the herbaria of the Bailey Hortorium, Harvard University, the University of Michigan, and the National Arboretum, at which institutions their identity has been confirmed.

An asterisk is used to indicate those species which are, so far as is known, new to Michigan.

### LIST OF SPECIES

\**CALAMOVILFA LONGIFOLIA* (Hook.) Scribn. — On the Grand Trunk railroad right-of-way, six miles southwest of Schoolcraft in Section 32, Prairie Ronde Township, August 1, 1936, no. 226.

*C. longifolia* is adventive in Michigan. It comes from the Great Plains. Our native grass that grows on sand dunes and beaches along Lake Michigan is *C. longifolia* var. *magna* Scribn. and Merr. The branches of the panicle of the Great Plains plant are nearly erect, with the spikelets usually white or greenish white, whereas in our native plant the branches are widely spreading, with the spikelets usually purple. L. H. Shinnars has discussed this species in the *American Midland Naturalist*.<sup>1</sup>

\**MUHLENBERGIA RACEMOSA* (Michx.) BSP. — Along the Grand Trunk railway two miles east of Schoolcraft in Section 21, Schoolcraft Township, September 7, 1943, no. 4316.

Professor Fernald<sup>2</sup> has shown that most of the herbarium

<sup>1</sup> Shinnars, L. H., "Notes on Wisconsin Grasses — III," *Am. Mid. Nat.*, 29: 779-782. 1943.

<sup>2</sup> Fernald, M. F., "Five Common Rhizomatous Species of *Muhlenbergia*," *Rhodora*, 45: 231-237. 1943.



specimens passing under the name of *M. racemosa* are really *M. setosa* (Spreng.) Trin. *M. setosa* is our common grass growing in marshy or boggy meadows, while *M. racemosa* is a western species of dry regions. The two species strongly resemble each other.

The grass has found favorable conditions along the railway. It is in dry soil and is quite short and so tough that the section crew does a very poor job in mowing it. It has been here for several years and is gradually spreading.

- \**ARISTIDA INTERMEDIA* Scribn. and Ball. — In sandy soil in an uncultivated field in Section 8, Brady Township, September 1, 1942, no. 2442.

This grass was well scattered over a part of the field. Associated with it was its relative *A. oligantha*.

- \**BULBOSTYLIS CAPILLARIS* (L.) C. B. Clarke var. *CREBRA* Fern. — Near the sandy shore on the southwest side of Austin Lake, August 23, 1935, no. 625; in a sandy field near Eagle Lake, Texas Township, August 6, 1941, no. 19341.

We have also found this variety on the east shore of Austin Lake and in a sandy field north of Sugarloaf Lake. The species *B. capillaris* (L.) C. B. Clarke has been collected in at least three different locations in Kalamazoo County. At the base it has crowded sessile spikelets, which the variety does not have. Our limited experience shows the plants of the species to be much smaller than those of the variety.

- \**CAREX RETROFLEXA* Muhl. — In the lawn on the M. P. Thomas property, Schoolcraft, July 4, 1943, no. 436.

This probably is not native but a waif that has come in grass seed. In reviewing it F. J. Hermann says: "First substantiated record for Michigan."

- \**CERASTIUM VULGATUM* L. var. *HIRSUTUM* Fries f. *GLANDULOSUM* (Boenn.) Druce. — Swamp in Section 33, Climax Township, June 18, 1941, no. 13341; low grassy meadow in Section 6, Alamo Township, June 11, 1943, no. 4338.

This is a rare form of *Cerastium vulgatum*. We have examined scores of plants in all parts of Kalamazoo County and have found colonies of the glandular form in only these two places.

These collections were two years apart.

- \**SMILACINA RACEMOSA* (L.) Desf. var. *CYLINDRATA* Fern. — Hilly

wood in Section 29, Oshtemo Township, June 11, 1943, no. 4317.

Though we have collected several specimens of this variety from widely separated sections of the county the plant from Oshtemo Township is the most typical. Our determination was confirmed by Professor Fernald.

\**RUBUS UVIDUS* Bailey.<sup>3</sup> — Swamp east of the railway station at Vicksburg, August 3, 1942, F. W. Rapp, no. 6203.

This new species of blackberry has been found so far in only the one location. It runs about under bushes and is associated with more erect varieties.

\**RUBUS MERACUS* Bailey.<sup>4</sup> — On a poplar-wooded slope near a marsh, one and one-half miles southeast of Alamo, June 26, 1939, no. 439.

Only one station has been discovered for this new species. It is a long-running plant resembling somewhat *R. flagellaris* Willd.

\**RUBUS SCHOOLCRAFTIANUS* Bailey.<sup>5</sup> — Type station in an oak wood in Section 30, Pavilion Township, August 3, 1942, no. 1717.

L. H. Bailey published this new species of the *Flagellares* group in March, 1943. It was named by him in honor of Henry Rowe Schoolcraft, from whom our own village of Schoolcraft received its name. Although previously undescribed, this bramble should not be rare in Michigan since we have collected it at one or more stations in Alamo, Comstock, Kalamazoo, Oshtemo, Pavilion, Schoolcraft, and Texas townships.

Our experience with *R. Wheeleri* shows how the genus *Rubus* has been neglected. In 1940 we reported before the Michigan Academy<sup>6</sup> one station in Kalamazoo County for this blackberry. It was near Hampton Lake in Portage Township. Since then we have found the species at three other locations in Portage Township, two in Climax Township, three in Schoolcraft Township, and four in Texas Township. In our county *R. Wheeleri* is among our commonest species of *Rubi*.

\**EPILOBIUM HIRSUTUM* L. — In low ground one and one-half miles northeast of Portage, August 5, 1943, H. R. Becker, no. 4362.

The flowers of this species are large and showy like those of *E. angustifolium*. It differs from that species, however, in that

<sup>3</sup> *Gentes Herbarum*, V: 304. 1943.    <sup>4</sup> *Ibid.*, p. 357.    <sup>5</sup> *Ibid.*, pp. 330-332.

<sup>6</sup> Hanes, Clarence R., "Additions to the Flora of Michigan. III," *Pap. Mich. Acad. Sci., Arts, and Letters*, 26 (1940): 22. 1941.

the pubescence is greater, the leaves are serrulate, sessile, and clasping, and the bracts subtending the pedicels of the flowers are of greater length.

- \**SOLIDAGO GRAMINIFOLIA* (L.) Salisb. var. *REMOTA* (Greene) Harris (*S. remota* (Greene) Friesner). — Pine Island Lake, September 14, 1935, no. 3215; Austin Lake, August 22, 1942, no. 5342.

This goldenrod is quite common on the sandy shores of Austin, Eagle, and Pine Island lakes and in some places on the east border of Bishop's Bog, in Section 28, Portage Township. We did not realize that the species was rare until we sent specimens to R. C. Friesner and L. H. Shinnars, both of whom knew of no records for Michigan. I quote Dr. Shinnars: "So far as I am aware, this [goldenrod] has previously been known only from the Indiana dunes. Quite distinct. Another plant belonging with the '*Coastal Plain*' element; whether actually connected with the Coastal Plain or not, the term signifies a definite group of midwestern plants with distinctive ranges."

- \**CENTAUREA DIFFUSA* Lam. — In an uncultivated field on the south boundary of Section 35, Richland Township, July 23, 1943, no. 433.

More than twenty plants occupied a small area of the field. Intermingled with them was the quite common relative *C. maculosa*. To the present this plant has been reported from only a few stations in the United States, but its weedy nature will soon make it more plentiful. Professor Fernald confirmed the determination given above. Dr. Blake stated that it was the nearest to *C. diffusa*.

SCHOOLCRAFT, MICHIGAN

## "ROOT NODULES" ON ZINNIA PRODUCED BY NEMATODES \*

KENNETH LESTER JONES

ON OCTOBER 15, 1943, while preparing a flower bed for the setting out of tulips, I noticed that all the Zinnia plants (six) had root galls (Pl. I, Fig. 1). They had shown no outward sign of disease. Plants of the genera *Ageratum*, *Pelargonium*, and *Gladiolus* in the same bed had no growths on their roots.

I assumed that the galls were of nematode origin, although I had not previously seen any which were so much like bacterial nodules. Since illustrations of similar galls on other genera occur frequently in the literature (e.g. Goodey, 1933, p. 103; Fred, Baldwin, and McCoy, 1932, pl. 5), they are probably common. The roots were washed, wrapped in wax paper, and placed in a refrigerator. The following day the galls were dissected for nematodes. Curiously, none were found, but, instead, small rod-shaped or clavate bacteria abounded and could oftentimes be seen within the parenchymatous cells. The galls were firmly cellular, not decaying.

The surfaces of some galls were sterilized in a 2 per cent mercuric chloride solution and flamed in alcohol. Suspensions of the contents of individual galls in sterile water were plated in nitrogen-free mannitol agar and in the same medium (Fred and Waksman, 1928), with 0.1 per cent  $\text{NaNO}_3$  added. The cultures were incubated at 28° and 16° C. Results were very similar on all plates, although the rate of growth was less at the lower temperature and in the absence of nitrogen. Over 95 per cent of the colonies have the following characteristics: diameter 5 mm., shape circular, margin entire, elevation convex, surface smooth and glistening, colorless or whitish, and texture slimy to gummy. The bacteria from these colonies were actively motile, gram-negative rods 0.5–1.5  $\mu$  in length, occurring singly or occasionally in pairs. A few colonies on the plates were

\* Papers from the Department of Botany of the University of Michigan, No. 739.

obviously of a different origin and for the most part proved to be endospore-forming bacilli. Only one actinomycete colony appeared.

The predominant bacterium was isolated and its cultural characteristics studied. It resembles very closely the description in *Bergey's Manual* (1939, p. 97) for *Alcaligenes radiobacter*, although there is also some similarity to the closely related *Rhizobium*. The characteristics are as follows:

*Small rods.* — Average size 0.5 by 1.3  $\mu$ , occurring mostly singly but occasionally in pairs. Actively motile, gram-negative.

*Nutrient gelatin stab.* — No liquefaction. Surface growth grayish and thick. A slight growth occurs throughout the length of the stab.

*Nutrient broth.* — Very slight surface growth of small colonies. Broth faintly turbid and also some large tufts of a whitish growth, which later form a sediment.

*Litmus milk.* — Serum zone with pellicle developing in one week; alkaline; no ropiness; a brown color appears in two weeks.

*Nitrates.* — No reduction.

*Sugars.* — No acid or gas in dextrose, lactose, sucrose, or mannite. A very thick, slimy pellicle forms and the medium usually becomes more alkaline.

*Indol.* — Not formed.

Growth occurs within twelve days at 16° C. (but not at 28° C.) in special media more alkaline than pH 11 (Hofer, 1935).

This saprophytic bacterium is a frequent contaminant in legume inoculants (Hofer, 1935). *Bergey's Manual* (1939) places it in the family Rhizobiaceae and states that its "inability to produce crown galls or root nodules distinguishes this organism from *Phytomonas tumefaciens* and *Rhizobium spp.*"

Galls were fixed in formalin-acetic acid-alcohol and the sections stained with gentian violet. Preliminary study of these revealed bacterial strands — apparently mostly of a slime, which made staining of the microbes difficult — extending into the galls in a tortuous manner from the periphery. They were too wide to be confused with infection threads of a bacterial nodule. Otherwise the tissue was free of microorganisms. However, further examination revealed nematode larvae at the ends of clear tunnels; backward some distance toward the exterior of the gall these tunnels were filled with the bacterium and its slime (Pl. I, Fig. 2<sup>1</sup>). Nematodes were thus the primary invaders and no doubt produced the galls. Their specific identity is difficult to determine since only larvae and eggs have been observed.

<sup>1</sup> The photograph was taken by Professor C. A. Arnold.

*Alcaligenes radiobacter* had found these tunnels particularly inviting and for some reason had taken them over practically to the exclusion of other microbes. Kostoff and Kendall (1930) believe that in tobacco galls nutrients accumulate in the vicinity of the worms because a toxic secretion discharged by them increases the permeability of the cortical cells. It would seem that these bacteria thrive on such materials and perhaps on the exudates of the worms. They were present in cells lining the tunnels, which resembled the granular giant cells figured by Kostoff and Kendall. Secondary invaders have been reported for other nematode galls. Muir and Henderson (1926), as reported by Goodey (1933, p. 110), "found a fungus always associated with tissues invaded by the parasite, and when cultured this fungus gave the same colour as the discoloured roots." Némec (1911) reported that dead syncytia are invaded by fungi and bacteria, and Triffitt (1931) observed hyphae of *Colletotrichum atramentarium* in rootlets attacked by *Heterodera schachtii*. I do not know how frequently root galls form in *Zinnia*. I find no mention of them in the literature, and plants friends brought to me from several gardens failed to show these structures.

#### SUMMARY

Healthy *Zinnia* plants from one garden all possessed root galls apparently produced by nematodes. The tunnels of the nematodes and the cells lining them were practically filled with one saprophytic bacterium, the slime producing *Alcaligenes radiobacter*.<sup>2</sup>

UNIVERSITY OF MICHIGAN

<sup>2</sup> Thirty-six *Zinnia* plants were grown in the same flower bed in 1944, and only one developed root galls. The soil had not been altered or treated in any way.

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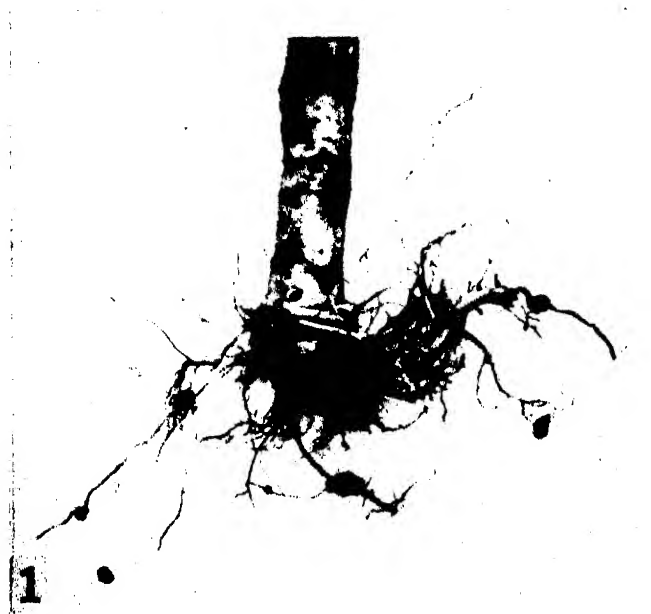


FIG. 1. "Root nodules" (galls) on *Zinnia*, produced by nematodes



FIG. 2. Interior of a gall, showing two nematode larvae at the ends of clear tunnels. The darkened material filling the outer portions of the tunnels is a slime produced by a secondary invader, *Alcaligenes radiobacter*





# A MONOGRAPH ON THE GENUS CYSTODERMA \*

ALEXANDER H. SMITH

*University of Michigan*

AND

ROLF SINGER

*Harvard University*

THE genus *Cystoderma* was established by Fayod (1889) to include certain agarics placed in the tribe *Lepiota* of *Agaricus* by Fries (1821). Fayod listed *Lepiota amianthina*, *L. granulosa*, *L. cinnabarina*, *L. carcharias*, *L. seminuda*, and *L. fumoso-purpurea* as belonging in it and *L. Georginae* as a possible additional species. As the name indicates, he placed greatest emphasis on the character of the universal veil. The other characters he mentioned, such as the differentiated cortex and pith of the stipe, the fragility of the lamellae, and the branching of the hyphae forming the subhymenium, are not recognized as significant in distinguishing genera among the gill fungi. The regular gill trama and the spore characters are important, but as given by Fayod they do not separate *Cystoderma* from *Lepiota*.

Fayod's genera were disregarded for many years, no doubt in part because they were based on morphological and anatomical studies which could be made only with the use of a microscope, and in part because of the great popularity of the Friesian system and the general acceptance of it throughout the world. However, as microscopic characters began to assume a major rôle in the classification of agarics, it became apparent that Fayod, in spite of many errors, had charted the course modern studies of agarics were to take, and his work has recently been receiving more attention.

Since Fayod listed *L. amianthina*, *L. granulosa*, *L. cinnabarina*, and *L. carcharias* first, it is obvious that these should be regarded as typifying the genus, and *L. amianthina* is here recognized as the type.

\* Contribution from the Herbarium of the University of Michigan and from the Laboratory of Cryptogamic Botany and the Farlow Herbarium, Harvard University.

Of the other species he listed, *L. seminuda* and *L. Georginae* have free gills, and it appears best to retain them in *Lepiota*. *L. fumoso-purpurea* is apparently the same as *Agaricus echinatus* Fr. and therefore must also be excluded.

From the time of its publication down to the present *Cystoderma* has had a varied history. Many investigators disregarded it. Konrad and Maublanc (1924-37) recognized it as a genus in the *Tricholoma* series. In their definition they characterized it as lacking cystidia. Earle (1909) recognized the genus, but defined it as having free gills. He listed *L. amianthina*, a species with attached gills, as the type. Kühner and Maire (1934) recognized it as a genus, but later Kühner (1936) included it in *Lepiota*, part in his section *Granulosae* (*L. granulosa*, etc.) and part, *L. seminuda* and its relatives, in the *Micaceae*. Lange (1935) had considered it a subgenus of *Lepiota*, but excluded *L. seminuda*. Singer (1939) used Kühner's 1936 concept, but recognized it as a genus consisting of the two sections mentioned above. The section *Micaceae* of Kühner, in addition to *L. seminuda*, contains *L. Bucknallii*, *L. Hetieri*, *L. Eyrei*, and *L. (Agaricus) echinata*. We have excluded the *Micaceae* from *Cystoderma* because the species in this section have free gills, or, at the most, the gills become only secondarily attached to the stipe and are very readily separated from it. Another character which is mentioned in the literature is that in *Lepiota* the stipe is readily separable from the pileus, whereas in *Cystoderma* the stipe and the pileus tissues are confluent, and, consequently, the two do not separate readily. We have not checked this character on fresh material to determine whether an anatomical difference in this respect actually exists between the groups in question, and so we have not emphasized the character here.

Kauffman (1923) transferred many of the species here placed in *Cystoderma* to *Armillaria*, but this disposition of them has not helped in clarifying the status of the latter genus. Investigators have long been aware of the difficulties of recognizing the genus *Armillaria* in the Friesian sense, and various arrangements have been made for its species (see Kauffman, 1923). Singer (1939) recognized *Catathelasma* (= *Biannularia*), *Armillariella*, and *Armillaria*, besides placing some species such as *A. focalis*, *A. caligata*, and *A. cinzulata* in *Tricholoma*. Whatever disposition is made of the Friesian genus *Armillaria*, it must be admitted that the species of *Cystoderma* stand out as a group not closely related to any other group in *Armil-*

laria, so that we prefer to treat them separately rather than as one of several unrelated subdivisions in a highly artificial genus.

In none of the works mentioned above has there been any attempt to treat critically the species of *Cystoderma* from a single region or to monograph them. Most investigators have assumed that the group was composed of *C. granulosum*, *C. cinnabarinum*, *C. amianthinum*, and *C. carcharias*, and since all these were supposedly well-known fungi, the need for critical studies did not seem urgent. We must acknowledge here that we approached the study of the group with much the same attitude, with the result that our observations in the field were limited more or less to times when other fungi were not demanding our undivided attention. However, attempts to identify the North American species continually brought the senior author to the realization that there were some unsolved problems in the genus. Consequently, this joint critical study was eventually undertaken for the purpose of reclassifying the species, if possible, on the basis of characters more reliable than those emphasized in the Friesian classification.

#### ACKNOWLEDGMENTS

We wish to express our appreciation to Dr. H. D. House, state botanist, New York State Museum, for the opportunity of studying the collections of Dr. Charles H. Peck. These collections are deposited in the New York State Museum, Albany, New York. Through the kindness of Professor E. B. Mains, director of the University of Michigan Herbarium, we had access to the notes and collections of C. H. Kauffman, the unpublished illustrations of L. C. C. Krieger, and also other materials pertinent to this study. Dr. David H. Linder, curator of the Farlow Herbarium, Harvard University, permitted us to inspect the material deposited in the Farlow Herbarium, including that collected by W. G. Farlow. We are also indebted to Professor H. M. Fitzpatrick, Cornell University, Ithaca, New York, who permitted us to examine authentic material of *Lepiota rhombospora* Atkinson from the Atkinson Herbarium. Dr. J. Walton Groves, of the Division of Botany and Plant Pathology, Department of Agriculture, Ottawa, Canada, made available to us the collections in the mycological herbarium of that department. Dr. S. M. Zeller, Oregon State College, Corvallis, Oregon, allowed us to examine his collections, which are important because of the long-

standing interest he has had in the genus. Dean L. R. Hesler, of the University of Tennessee, turned over to us the collections in the Herbarium of the University of Tennessee. These are of special interest not only because of a new species discovered among them, but also because of range extensions, which we were able to verify. To Mr. Maurice B. Walters, of Cleveland, Ohio, to Mr. William B. Gruber, of Portland, Oregon, and to Dr. D. E. Stuntz, University of Washington, Seattle, Washington, we are under obligation for both collections and photographs.

#### DEFINITION AND LIMITS OF THE GENUS

Spore deposits white; spores smooth, ellipsoid to subglobose or ventricose to subrhomboid, either amyloid or nonamyloid; pleurocystidia and cheilocystidia sometimes present; gill trama typically regular to subregular, hyaline to pale cinnamon in KOH, nonamyloid; pileus trama with the cuticle formed by chains of inflated cells (sphaerocysts) or the cells ellipsoid to cylindric or quite irregular in some, the walls either hyaline, olivaceous, or strongly yellowish to cinnamon or russet in KOH, smooth or with an incrusting pigment, clavate-pedicellate cells sometimes present in the cuticle in addition to the sphaerocysts; subcuticular hyphae filamentous but in some species with a KOH reaction similar to the sphaerocysts (when the subcuticular hyphae show a strong KOH reaction a larger percentage of clavate to cylindric cells are usually present in the cuticle); flesh hyaline to cinnamon in KOH, the hyphae regularly with clamp connections; lamellae regularly attached to the stipe, adnate, adnixed, sinuate, or subdecurrent, sometimes seceding; stipe confluent with the pileus and sheathed with a coating of sphaerocysts or enlarged ellipsoid cells similar to those forming the cuticle of the pileus, or the sheath made up of an inner layer which is fibrillose to membranous and with the chains of sphaerocysts thinly coating its outer surface; annulus either present and flaring as well as quite persistent or evanescent to scarcely forming; habitat either terrestrial or lignicolous; stipe fleshy and centrally attached.

Type species: *Agaricus amianthinus* Scop. ex Fries,  
Hymen. Eur., p. 37. 1874.

The definition given above excludes the species of *Tricholoma* which lack clamp connections, all species of *Lepiota* with free gills,

and the species of *Tricholomopsis*. The last do not have sphaerocysts making up the cuticle of the pileus. In the light of the results of our investigation the arrangement proposed by Konrad and Maublanc (1924-37) has much to recommend it. These authors placed *Cystoderma* in the *Tricholoma* series. Further studies on the relationship of *Cystoderma* to *Tricholomopsis* (*T. rutilans*, *T. decora*, and others) are needed, but the similarities between the species of *Cystoderma* and those in *Lepiota* also having sphaerocysts that make up the cuticle of the pileus should not be considered merely accidental. The clarification of this problem rests in part on whether or not the separable pileus of the species of *Lepiota* can be demonstrated to be an important difference and in part on further critical studies of some of the poorly known species of *Lepiota*. The white spore deposit at once distinguishes *Cystoderma* from all gill fungi with colored spores which have a somewhat similar universal veil. *Phaeolepiota aurea* (Fr.) Maire (*Pholiota aurea* of the Friesian system) is the most likely to be mistaken for a species of *Cystoderma*, and we have included it in our key as an aid to its quick identification. It has the appearance of a gigantic *C. granosum* and, indeed, was described as a *Lepiota* by Quélet. The color of the spore deposit also distinguishes the genus *Cystoderma* from *Naucoria*. In fact, a possible intermediate species is *C. rhombosporum*, which has spores of the same peculiar shape as those in some of the ocher-spored agarics, and the same type of cheilocystidia, but lacks the incrusting pigment usually present on the hyphae of the cuticle of the pileus in that group, and, as it is described, has colorless spores in deposits. It needs further study from fresh material, but in the dried condition does not appear to be referable to any known species in the ocher-brown-spored series. The development of chains of sphaerocysts in the universal veil of one species of *Deconica*, *D. tomentosa* Murrill, has recently come to the attention of the senior author. It is interesting to see this character present in groups of fungi with such different spores, and one is reminded once again that the same characters have arisen independently in various groups of gill fungi. At least there appears to be no close relationship between the *Deconica* mentioned and either *Cystoderma* or *Naucoria*. This situation complicates the study of relationships between groups of agarics and makes us reluctant at present to do more than suggest possibilities.

## COMMENTS ON THE CHARACTERS OF THE SPECIES

The synonymy of the European species will illustrate the history of the group. Most of the species now recognized were at first included under the old name *Agaricus (Lepiota) granulatus*. Murrill (1914) listed all the known North American species as synonyms of *Lepiota amianthina*. The failure of investigators properly to evaluate the species in this group can be traced in large measure to the characters imposed upon them by the Friesian system. Such characters as the color of the pileus, the attachment of the gills, the degree to which the annulus develops, and the nature of the scales over the lower part of the stipe are variable to the extent that they have caused great confusion in the differentiation of species by those who attempted to recognize more than one. We have amply established this point as a result of studying the specimens identified by many previous investigators. One of the reasons for our finally undertaking this study was the confusion we found when trying to compare our own identifications with those of others. It was apparent from the start that a satisfactory classification could be arrived at only by the use of characters not previously widely employed.

The use of the iodine reaction of the spores in *Cystoderma* as introduced by the French mycologists, particularly Kühner and Maire (1934), furnished the first and most important character in erecting a new and more usable as well as a more natural classification of the genus. They found two series of species existing in the group: one with nonamyloid spores containing *C. cinnabarinum*, and one with amyloid spores containing *C. amianthinum*, *C. carcharias*, and *C. haematites*. We have verified the importance of this character in our studies and have used it to divide the genus into two sections.

A second important character was soon discovered during the course of studying herbarium specimens. When revived in alkaline solutions the cuticular and subcuticular cells and hyphae of some species assume a strong cinnamon, reddish, or deep rusty-brown color. In others no reaction is observed; in one an olive-gray reaction was discovered. We have found these reactions to be distinct enough to justify grouping the species in the sections according to their reactions in alkaline solutions. Spore characters have been used to recognize species or varieties, depending on the degree of difference found. In the *C. amianthinum* series, because of the number of

intermediate units present, spore size has been made a varietal distinction. The same is true for the KOH reactions of the flesh of the pileus and the gill trama. Either these tissues do not react or the color produced is faint and variable in different gills or parts of the pileus. The important point to bear in mind here is whether or not any distinct color reaction is observed in any of the tissues concerned. A number of sections must be examined, and the sections must be thin enough to allow the details of the gill trama to be observed.

Contrary to the statement by Konrad and Maublanc (1924-37), cystidia are known in *Cystoderma*, and we have placed emphasis upon their type, if present, and on whether cheilocystidia are present or absent. We have used the presence of cheilocystidia as the deciding character by which *C. cinnabarinum* is distinguished from large forms of *C. granulosum*. This emphasis on cystidia is in keeping with that placed upon it throughout the classification of white-spored agarics. Variability in the number present is found here, however, as elsewhere in the gill fungi. In *C. cinnabarinum* we have occasionally collected carpophores in which both pleurocystidia and cheilocystidia were very abundant, and others in which pleurocystidia were rare to scattered or apparently absent. In *C. granosum* cheilocystidia of the clavate type are characteristic. In *C. rhombosporum* they are the usual fusoid-ventricose type, but in *C. amianthinum* only occasional cheilocystidia occur. So far as our present information goes, they are too rare to be considered a valuable taxonomic character.

The attachment of the gills, the color of the pileus, the taste and odor of fresh material, the degree to which the annulus develops, and the habitat are all secondary characters, and are the ones that were too variable for purposes of precise classification. These are not without value in isolated instances, however. The habitat and the degree of development, along with the persistence of the annulus, are useful in conjunction with the iodine and KOH reactions. In *C. granosum* habitat appears to be constant and distinctive, whereas in *C. amianthinum* it is not. The annulus in *C. carcharias*, *C. granosum*, and *C. fallax* is membranous and usually persistent; it furnishes a good field character in spot identification. The attachment of the gills needs to be critically studied in relation to the iodine and KOH reactions. It may prove to be fairly constant and helpful



in the field. We have used the color of the pileus and sheath of the stipe to distinguish forms when they are not correlated with other significant differences. In most species we have found it rather variable, but in *C. granosum*, *C. fallax*, and *C. subvinaceum* it appears, from the information available, to be quite constant.

#### COMMENTS ON THE ARRANGEMENT OF THE SPECIES

Certain very distinct evolutionary trends are evident within the genus, and it is upon these that we have based our classification. The most primitive species is *C. Ambrosii*. This is evident from the nonamyloid spores, the relatively abundant filamentous hyphae present among the chains of sphaerocysts in the cuticle of the pileus, and the lack of a distinctive KOH reaction by the cells of the cuticle. Next in the nonamyloid series we have placed *C. granulosum*, with its variants. They are distinguished from *C. Ambrosii* by the positive reaction to KOH by the cuticle of the pileus and by their brighter or their darker colors. *C. ponderosum* is placed next after *C. granulosum* because of the apparent reduction in the formation of sphaerocysts and the failure of those formed to separate from one another readily. We consider this a retrogression because in *C. granulosum* and its forms a tendency toward the reduction of sphaerocysts and greater differentiation of the subcuticular hyphae was noted. *C. ponderosum* is thus regarded as a branch of the *granulosum* series. The latter is continued in *C. cinnabarinum* and *C. australe*. The cheilocystidia of these species indicate that they have attained a higher level of development than the others. Apparently both have been derived from *C. granulosum*. *C. rhombosporum* is placed at the end of the series. Because of the lack of a distinctive KOH reaction in the subcuticular cells of the pileus some might be inclined to consider it a branch from *C. Ambrosii*. Its cheilocystidia and spores indicate, however, a higher level of development, and since the KOH reaction of the subcuticular hyphae of *C. cinnabarinum* is not so strong as in *C. granulosum* and since it is almost lacking in *C. australe*, we may assume that in Atkinson's species the character has retrogressed still further.

In the second series are grouped species having amyloid spores. *C. carcharias* is placed at the bottom because of the negative reaction of the cuticle in KOH. *C. pulveraceum* is placed above it because of the lignicolous habitat and because many of the cuticular cells

show further differentiation in the form of a filamentous apical proliferation. *C. caucasicum* is arranged after *C. pulveraceum*. It shows colored cuticular elements in alkaline solution and is thus closer to *C. amianthinum*, which is represented by a large aggregate of forms. There is a rather wide range in spore size, as well as considerable difference in the intensity of the coloration, and the species is further characterized by the almost complete suppression of cylindric or elongated cells in the cuticle of the pileus. *C. fallax* is distinguished by its consistently smaller spores, generally darker colors, and more persistent annulus, and appears to occupy an intermediate position between *C. amianthinum* and *C. granosum*. *C. granosum* is placed at the end of this series by virtue of its size, cheilocystidia, and habitat.

We have placed *C. haematites* with *C. subvinaceum* in the third series because of its resemblance, at least superficially. We have no data on the KOH reaction of the cuticle of its pileus. This series is characterized by the olivaceous-gray color assumed by the cuticular cells when treated with KOH and is based on *C. subvinaceum*. It may have been derived from *C. carcharias*.

In the following account fourteen species are recognized in *Cystoderma*. Five new ones, *C. caucasicum*, *C. australe*, *C. fallax*, *C. ponderosum*, and *C. subvinaceum*, are described. In *C. amianthinum* a new variety, var. *sublongisporum*, and a new form of var. *typicum*, f. *olivaceum*, are proposed along with var. *occidentale* in *C. granulosum*. During the course of our study we have been able to establish the occurrence in North America of twelve of the fourteen species. *C. haematites* and *C. caucasicum* are the two exceptions. The former is known only from Europe (England, France, and Italy), and the latter only from the Caucasus Mountains. *C. amianthinum* var. *longisporum* has not been reported in North America, and *C. granulosum* var. *occidentale* as well as *C. amianthinum* var. *sublongisporum* are varieties not known outside North America. Six of the species have been found in Europe. To this number *C. fallax* should perhaps be added, since Kühner and Maire (1934) have commented on a puzzling agaric which appears to be this fungus.

Information concerning the distribution of the species is still incomplete. In general, however, it can be said that the common species such as *C. amianthinum*, *C. granulosum*, and *C. cinnabarinum* are circumpolar in distribution since they are known from Europe,

Asia, and North America. *C. granulosum* and *C. amianthinum* have been reported from Japan by Imai (1938), and the latter apparently also occurs in Australia as *Armillaria muscicola* (see Cleland, 1934). Maire (1937) has reported *C. amianthinum* and *C. granulosum* from Morocco in North Africa.

#### GENERAL CONSIDERATIONS

The techniques used in the study were the standard procedures now current in the study of gill fungi. The iodine tests were made with Melzer's reagent, which is composed of equal parts (20.0 gr. each) of chloral hydrate and water, 1.5 gr. of KI, and 0.5 gr. of iodine crystals. The KOH reactions were obtained with a 2.5 per cent solution. This is the customary reagent employed to revive sections of dried material.

In the paragraphs listing material studied the following abbreviations are used:

CU = Cornell University, Ithaca, New York.

FH = Farlow Herbarium, Harvard University, Cambridge, Massachusetts.

L = Cryptogamic Herbarium of the Academy of Science, Leningrad, U.S.S.R.

MO = Mycological Herbarium of the Department of Agriculture, Ottawa, Canada.

NY = New York Botanical Garden, New York City.

NYS = Herbarium of the New York State Museum, Albany, New York.

UM = Herbarium of the University of Michigan, Ann Arbor, Michigan.

UT = Herbarium of the University of Tennessee, Knoxville, Tennessee.

UW = Herbarium of the University of Washington, Seattle, Washington.

Z = Herbarium of S. M. Zeller, Oregon State College, Corvallis, Oregon.

#### KEY TO SPECIES

- I. Spore deposit yellowish; carpophore rich ochraceous brown; large, terrestrial; annulus flaring and membranous ..... *Phaenolepiota aurea*
- II. Spore deposit white
  - A. Spores nonamyloid
    1. KOH not coloring the cuticular cells of the pileus or, if so, only a pale yellowish tint developing ..... 1. *C. Ambrosii*
    2. KOH causing the cuticular cells to become tawny to deep rusty brown or reddish
      - a) Spores ellipsoid to subglobose
        - (1) Subcuticular and cuticular cells not with conspicuous incrusting pigment (pigment in the cell wall instead)
          - (a) Cheilocystidia absent ..... 2. *C. granulosum*
          - (b) Cheilocystidia present
            - (i) Terrestrial, large, and fleshy; cap usually cinnabar red to orange ..... 4. *C. cinnabarinum*

- (ii) Lignicolous, small, cap rusty brown; southern in distribution ..... 5. *C. australe*
- (2) Subcuticular and cuticular cells with an incrusting pigment as seen when revived in KOH ..... 3. *C. ponderosum*
- b) Spores subrhomboid to ventricose-apiculate ..... 6. *C. rhombosporum*
- B. Spores amyloid
- 1. KOH not coloring the cuticular cells (see also 2 and 3)
  - a) Terrestrial; cuticular cells not with a filamentous proliferation ..... 7. *C. carcharias*
    - (1) Pileus slightly colored pinkish to lilaceous ..... f. *typicum*
    - (2) Pileus white ..... f. *album*
  - b) Lignicolous; cuticular cells sometimes proliferated ..... 8. *C. pulveraceum*
- 2. KOH coloring the cuticular cells tawny to reddish or rusty (see 3 also for *C. haematites*, for which no KOH reaction is known)
  - a) Pigment brownish and dissolved in the cell sap in at least some cells (NH<sub>3</sub> mounts of dried material) ..... 9. *C. caucasicum*
  - b) Pigment located in the cell walls
    - (1) Spores usually 5  $\mu$  or more long ..... 10. *C. amianthinum* and varieties
    - (2) Spores usually shorter than 5  $\mu$ 
      - (a) Pileus 2-5 cm. broad; terrestrial, usually under conifers; cheilocystidia none ..... 11. *C. fallax*
      - (b) Pileus 4-9 cm., bright orange; clavate cheilocystidia present; on decaying hardwood logs ..... 12. *C. granosum*
- 3. KOH coloring the cuticular cells olivaceous gray
  - a) Gills unchanging when bruised; flesh of pileus and stipe pallid; on decaying wood ..... 13. *C. subvinaceum*
  - b) Gills white, becoming reddish when bruised. Flesh pale liver color, yellowish in stipe; terrestrial ..... 14. *C. haematites*

# SECTION I: GRANULOSA A. H. SMITH AND R. SINGER, SEC. NOV.

Sporis haud amyloideis.

## 1. *Cystoderma Ambrosii* (Bres.), comb. nov.

*Armillaria Ambrosii* Bresadola, Fung. Trid., 1: 27. 1881.

Illustrations: Bresadola, Fung. Trid., Vol. I, pl. 31; Icon. Mycol., pl. 50.

Pileus 4-5.5 cm. broad, broadly convex to nearly plane, surface dry and at first more or less covered with small white conic scales formed by tufts of fibrils and enlarged cells, in age more or less glabrescent or appearing cottony-fibrillose, snow white over all when young, in age flushed sordid tan (near "cinnamon buff"); flesh thick over the disc, tapered abruptly near the margin, whitish, odor

none, taste mild; lamellae close,  $85 \pm$  reach the stipe, 2-3 tiers of lamellulae, broad (up to 4-5.5 mm.) next to the stipe, tapered to the margin, adnate, becoming adnexed in age, whitish or tinged cream color, edges even, no color change noted on bruised portions; stipe 5-9 cm. long, 8-12 mm. thick, solid, equal, pallid within, surface white and more or less fibrillose to lacerate-scaly up to the apical zone left by the thin more or less fibrillose veil, in age somewhat glabrescent.

Spores ellipsoid, smooth, nonamyloid,  $4-5 \times 2.5-3 \mu$ ; basidia four-spored,  $22-28 \times 4-5 \mu$ ; pleurocystidia and cheilocystidia not differentiated; gill trama of interwoven hyphae, nonamyloid, lactiferous hyphae intermingled; pileus trama floccose beneath a surface layer of loosely arranged chains of globose to sausage-shaped thin-walled cells  $18-80 \times 18-50 \mu$ , filamentous hyphae intermingled, all hyaline to very slightly yellowish in KOH, tramal body nonamyloid, clamp connections abundant.

*Habitat.* — Under larch in mossy places or under alder in mixed alder, cedar, and Douglas fir forests. Very rare.

*Distribution.* — Originally described from northern Italy but also found along the Santiam River, Cascade Mountains, Oregon. The area occupied by this species still remains to be delimited.

*Material studied.* — Smith, 18185 (FH, UM), Oct. 31, 1941. Santiam River, Oregon.

*Observations.* — The nonamyloid spores and the presence of a comparatively large number of filamentous hyphae in the tissue making up the veil are here considered primitive characters and, consequently, the species is placed at the bottom of the evolutionary series. It appears significant that these characters are correlated with negative KOH reactions on the cuticular and subcuticular cells. This fungus is most easily confused with *C. carcharias* f. *album* (see page 103), but is easily distinguished by the larger number of filamentous hyphae in the cuticle of the pileus and by the nonamyloid spores.

2. *Cystoderma granulosum* (Batsch ex Fr.) Fayod,  
Ann. Sci. Nat., Ser. 7, 9:351. 1889.

(a) Var. *typicum* f. *typicum*

*Agaricus granulosus* Batsch ex Fries, Syst. Mycol., I: 24. 1821.

*Agaricus granulosus* subsp. *ferruginea* Fries, Monogr. Hymen. Suec., 1: 29. 1857.

*Lepiota granulosa* S. F. Gray, Natural Arrangement of British Plants, 1: 602. 1821.

*Armillaria granulosa* Kauffman, Pap. Mich. Acad. Sci., Arts, and Letters, 2 (1922): 60. 1923.

Illustrations:

Plate I; Text Figure 1, spores.

Barla, Champ. Alp. Mar., pl. 16, figs. 5-8.

Batsch, Elench. Fung., fig. 24.

Bischoff, Kryptog., fig. 3464.

Bresadola, Icon. Mycol., pl. 599.

Britzelmayer, Hymen., pl. 1, fig. 2, and f. *sphagnorum*, pl. 111, fig. 569 (color somewhat too yellow).

Cooke, Illus. Brit. Fungi, no. 39, pl. 18.

Dufour, Atlas des Champ., pl. 7, fig. 12.

Farlow and Burt, Icones Farlowianae, pl. 10 (upper figures).

Gillet, Champignons qui croissent en France, pl. 44.

Hahn, Pilzsammler, fig. 9.

Harzer, Naturgetreue Abbildungen der Pilze, pl. 44, fig. A.

Hussey, Illus. Brit. Mycol., Vol. 1, fig. 45.

Krombholz, Naturgetreue Abbildungen und Beschreibungen der essbaren, schädlichen und verdächtigen Schwämme, pl. 1, fig. 2.

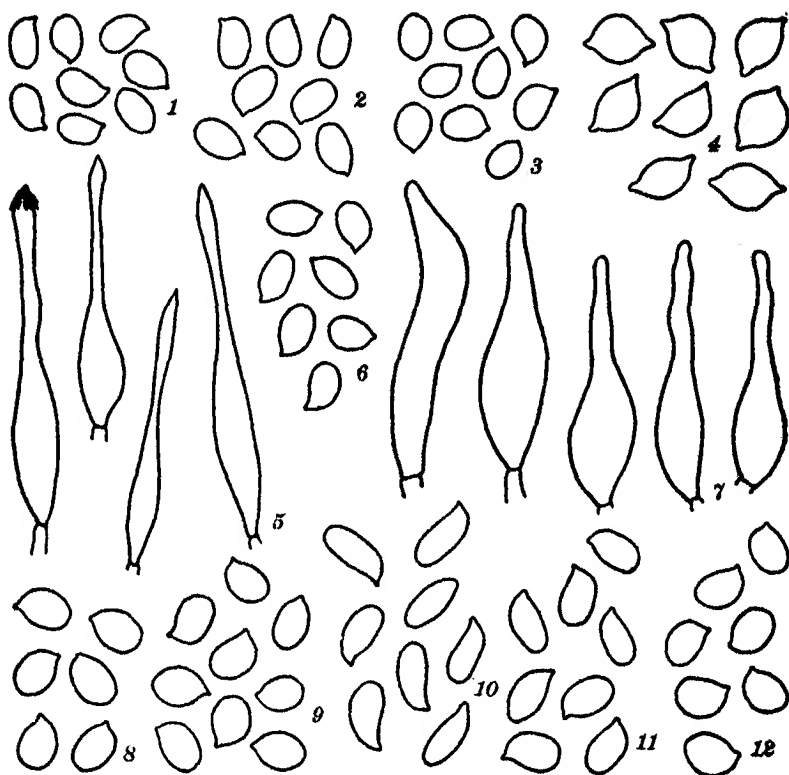
Patouillard, Tab. Anal. Fung., fig. 611.

Ricken, Die Blätterpilze, Vol. II, pl. 81, fig. 3.

Saccardo, Mycologiae Venetae Specimen, tab. 4, figs. 15-19, as var. *cortinata* (probably not *C. granulosa*).

Sicard, Hist. Nat. Champ., tab. 24, fig. 127.

Pileus 1.5-3 (4) cm. broad, ovoid to convex when young, broadly campanulate to plane, with or without an obtuse umbo in age, margin at first incurved slightly and appendiculate with the veil remnants, surface dry and granular-furfuraceous or covered with small conic granulose scales, even or radially wrinkled, color variable, sometimes evenly colored but often darker on the disc, russet to tawny, the margin paler and yellowish ("russet," "tawny," "ochraceous tawny," "ochraceous buff," or between "orange cinnamon" and "mikado brown"), usually dull reddish cinnamon when dried ("mikado brown" to "Sayal brown"), often with a hoary sheen, at times pallid vinaceous cinnamon; flesh thin, equal, whitish or flushed pale rufous, odor not distinctive, taste mild; lamellae adnexed and rounded next to the stipe or adnate with a decurrent tooth, close, broad and at times somewhat ventricose, white to pale yellowish or subconcolorous pallid away from the edges, not darkening appreciably in drying, edges even; stipe usually rather short in relation to the width of the cap, 2-4 (6) cm. long, 2.5-6 mm. (longer and up to 10 cm. in sphagnum), equal or slightly enlarged downward,



FIGURES 1-12

Spores and cystidia of *Cystoderma*

FIG. 1, spores of *C. granulorum* var. *typicum* f. *typicum*; FIG. 2, spores of *C. granulorum* var. *adnatifolium*; FIG. 3, spores of *C. ponderosum*; FIG. 4, spores of *C. rhombosporum*; FIG. 5, cheilocystidia of *C. cinnabarinum*; FIG. 6, spores of *C. cinnabarinum*; FIG. 7, cheilocystidia of *C. rhombosporum*; FIG. 8, spores of *C. fallax*; FIG. 9, spores of *C. carcharias*; FIG. 10, spores of *C. amianthinum* var. *sublongisporum*; FIG. 11, spores of *C. amianthinum* f. *typicum*; FIG. 12, spores of *C. granosum*.

The drawings were made with the aid of a camera lucida, and as reproduced those of the spores are approximately 1,650 times natural size and of the cystidia 750 times.

stuffed to hollow, pallid within, surface granulate-scaly to the evanescent pallid fibrillose apical annular zone or merely furfuraceous, concolorous with pileus below the annular zone, whitish and silky above.

Spores white in deposits,  $3.5-5 \times 2.5-3 \mu$ , ellipsoid, smooth, nonamyloid; basidia four-spored,  $18-20 \times 5-6 \mu$ ; pleurocystidia and cheilocystidia none; gill trama hyaline in KOH, homogeneous, the hyphae more or less regularly arranged; pileus trama with a cuticle of chains of cells  $10-50 \times 10-25 \mu$ , some globose and up to  $20 \mu$  in diameter, some subglobose to ellipsoid and up to  $50 \times 25 \mu$ , some more or less cylindric, with smooth brown walls when revived in KOH, the filamentous hyphae beneath the inflated cells also with rusty-brown walls in KOH, the hyphae progressively paler toward the gill trama, clamp connections present.

*Habitat.* — Scattered to gregarious on moss and soil under hardwoods as well as conifers. It usually fruits during the late summer and fall and is not uncommon.

*Distribution.* — This species is very widely distributed throughout north temperate regions. In Europe it is known from U.S.S.R., Finland, Sweden, Germany, Austria, Czechoslovakia, France, Italy, Spain, and England, and also from North Africa. In Asia it has been found in the Caucasus and Altai Mountains. In North America it has been collected in Nova Scotia, Quebec, Ontario, and Manitoba in Canada, and in the United States it occurs across the continent from Maine to Washington and south to Tennessee and Oregon.

*Material studied.* — Collections of fresh material have been studied as follows: Singer, Huntington Wild Life Forest, Newcomb, New York, Sept., 1941, 98 (FH); also material from the Caucasus and Altai Mts. of Asia and from various regions of the European part of the U.S.S.R. (L), and from Austria, France, and Spain: Smith, Rock River, Michigan, Sept. 12, 1929 (UM); Colchester County, Nova Scotia, 1931 (UM); Ann Arbor, Michigan, Oct. 1, 1933, 33-1049 (UM); Blue River, Oregon, Oct., 1937, 7919 (UM), 8075 (UM); Milford, Michigan, Sept., 1940, 18859 (UM).

The following collections of dried material have been examined: Farlow, Shelburne, New Hampshire, Sept., 1891, as *Ag. granulatus* (FH). Hesler, Knox County, Tennessee, Nov., 1941, 14053 (UT). Hotson, San Juan, Nov. 5, 1939, H. Hotson, Washington (UW). Kelly, Indian Point, Magnetawan, Ontario, Canada, Aug. 24, 1921, 1186 (UM). Kauffman, Ithaca, New York, Aug. 24, 1904, as *L. cinnabarina* (UM); Pend d'Oreille National Forest, Copeland, Idaho, Sept. 7, 1922, coll. Wehmeyer (UM); Lake Quinault, Washington, Oct. 31, 1925, coll. and det. Brown as *L. amianthina* (UM). Zeller,



Lincoln County, Oregon, Nov., 1934, coll. Burlingham (UM, Z); Canyonville, Oregon, Oct. 22, 1937 (UM, Z); Kilowan, near Falls City, Oregon, Nov., 1939 (UM, Z); the type of *A. granulosoidea* Zeller (UM, Z). The following collections were examined from the Mycological Herbarium of the Division of Botany, Department of Agriculture, Ottawa, Canada: F-7018, Mt. Burnet, Quebec, Sept. 27, 1936; F-7022, Graham's Bay, Ontario, Sept. 18, 1936; F-8765, Norway Bay, Quebec, Oct. 4, 1938; 10974, Burnet, Quebec, Sept. 7, 1942; 11420, Petawawa Forest Experiment Station, Ontario, Aug. 31, 1943; collection by Macoun, Canadian Cryptogams, 1, Beechwood, Ontario, as *L. amianthina*, Sept. 16, 1891.

*Observations.* — Although one of the supposedly well-known species of agarics, *C. granulorum* is by no means so sharply delimited from its close relatives as one might expect. Consequently, although we have listed the majority of the illustrations which have been published as *C. (Lepiota or Agaricus) granulorum*, we do not insist that they illustrate the species as we have recognized it here. Patouillard's figure 611 is an example. Even with the Patouillard collections available for study it is impossible to be sure that one has examined the actual carpophores from which the illustration was made. The figure in question could easily represent a somewhat rosy fruiting body of *C. carcharias*. The color of *C. granulorum* is quite variable, as is evidenced by the varieties *occidentale* and *adnatifolium*, as well as by the range given for var. *typicum*. Aside from these varieties, one often collects carpophores in various stages of being bleached, and these are at times almost impossible to distinguish from those of f. *albidum*. *F. sphagnum* Britzelmayer appears to be an exceptionally long-stiped form on sphagnum. We have not seen material of it and are inclined to regard it as a chance variation resulting from the habitat in which it was found. *Laccaria laccata* frequently shows a similar variation. In old weathered specimens sections of the pileus are likely to show very few of the separable globose cells characteristic of fresh young material, and these pilei appear to have the cuticle made up mostly of filamentous hyphae. Such old pilei are the ones which show best the hoary sheen mentioned by Kauffman, and in our estimation they represent the first stages of the bleaching out of the pileus. This may be observed on slowly expanding buttons as well as on mature carpophores. Near Mt. Hood, Oregon, buttons were observed to remain in the unexpanded state for two weeks.

(b) Var. *typicum* f. *albidum* (Peck), comb. nov.

*Lepiota granulosa* var. *albida* Peck, Ann. Rep. New York State Mus., 41: 82. 1888.

Pileus 1.5-2.5 cm. broad, convex to plane, minutely granulose-scaly, whitish when dried, the scales discolored slightly and brownish, when treated with KOH becoming dark rusty brown; gills moderately close, pallid when dried; stipe short, 2.5-3 cm. long, 3-5 mm. thick, lower portion slightly granulose in dried condition.

Microscopic characters as in f. *typicum*, with the exception that KOH reactions were not so pronounced. The subcuticular hyphae were pale cinnamon, and the few sphaerocysts found were only moderately dark cinnamon.

*Habitat*. — Scattered to gregarious on humus, in pastures, or on needle carpets under conifers.

*Distribution*. — New Hampshire, New York, Michigan, and Oregon.

*Material studied*. — Peck, Catskill Mts., New York, type (NYS); Farlow, Shelburne, New Hampshire, Sept., 1891, as *Ag. granulatus* (FH); Smith, Wilderness State Park, Emmet County, Michigan, Oct. 1934, 1239 (UM). Zeller, Canyonville, Oregon, Oct. 22, 1937 (UM, Z) (?).

*Observations*. — Zeller described the caps of his material as "putty gray to sand color," but in the dried condition they are indistinguishable from Peck's type. His specimens were also found in the open among grasses. The description given above is drawn entirely from Peck's type in order to avoid any possible confusion. It appears that Peck very probably had a truly persistently whitish form rather than merely faded specimens of f. *typicum*, but it is evident from our study of the material cited that faded collections of f. *typicum* are frequently going to be very difficult to distinguish from his form. It may be impossible to do so when herbarium specimens are not accompanied by proper notes.

(c) Var. *typicum* f. *robustum*, f. nov.

A forma typica differt magnitudine *Cystoderma cinnabarinum* in mentem revocante.

*Illustrations*:

Bresadola, Icon. Mycol., Vol. I, pl. 36.

Konrad et Maublanc, Icon. Sel. Fung., Vol. III, pl. 238.

Pileus 3-9 cm. broad, convex to plane, granulose-scaly, deep brick red ("brick red" to "Hay's russet"), but becoming paler in age, when dried near "Verona brown" (dark sordid vinaceous cinnamon); lamellae crowded, adnate to slightly adnexed; stipe 3-7 cm. long, 8-15 mm. thick, clavate, solid, sheathed with a double sheath up to the flaring more or less persistent floccose to submembranous annulus, the outer layer furfuraceous to scaly and concolorous with the pileus, inner layer pallid to cream color and fibrillose, both layers more or less worn away in age, silky and pallid or tinged pale tan to rufous violaceous toward the apex.

Spores  $4-4.5 \times 2.5-3 \mu$ , white in deposits, smooth, ellipsoid, nonamyloid; basidia four-spored,  $18-20 \times 4-5 \mu$ ; pleurocystidia and cheilocystidia not differentiated; gill trama with a central portion of strongly interwoven hyphae flanked on either side by a narrow band of more or less parallel hyphae, subhymenium very narrow and not distinctive; all parts hyaline in KOH, pale tawny in iodine; cuticle of pileus of globose to somewhat elongated cells with smooth bright reddish-brown walls in KOH, the cells  $10-25(40) \times 10-15(20) \mu$ , beneath this a region of reddish-brown filamentous hyphae gradually fading into the hyaline flesh toward the gills, these hyphae with incrusting pigment on the walls, clamp connections present.

*Habitat.* — Scattered to gregarious on humus in mixed forests or in pure stands of hardwoods as well as under conifers. Fall. Rare to uncommon.

*Distribution.* — In Europe it is known from France and Italy but is probably as widely distributed as the typical form. In North America it has been recorded from Maryland, New York, Michigan, Oregon, and Washington in the United States and from Quebec and Ontario in Canada.

*Material studied.* — Fresh specimens were studied as follows: Smith, Milford, Michigan, Sept. 15, 1938, 10967 — type (UM); Mt. Angeles, Port Angeles, Washington, Oct. 8, 1941, 17651 (UM); Detroit, Oregon, Oct. 31, 1941, 18196 (UM). The following collections of dried material have also been examined: Kauffman, Seventh Lake, Adirondack Mts., New York, Sept. 21, 1921 (UM). Kelly, Maryland, Aug. 29, 1920, 441 (UM). Zeller, Corvallis, Oregon, Dec. 3, 1934, 9200 (UM, Z). Drayton, Burnet, Quebec, Sept. 20, 1942, Ottawa, 11025 (MO). Odell, Hiawatha Park, Oct. 25, 1920, no number (MO).

*Observations.* — This form differs from *f. typicum* in attaining the size of *C. cinnabarinum*, and in its consistently more rusty-reddish colors. At times these are bright enough to cause some confusion with *var. adnatifolium*, which appears to be characterized by the more abundant, paler (in KOH) globose cells in the cuticle of the pileus and by a paler subcuticular region. Many collections will probably be difficult to place because of intergradations. Kelly, 441, appears to be intermediate between *f. typicum* and *f. robustum*.

(d) *Var. occidentale* A. H. Smith, *var. nov.*

Pileo 1–3 cm. lato, obtuso demum late convexo, sicco, granuloso, sordide vinaceo, demum avellaneo vel pallide vinaceo-brunneo; lamellis late adnatis vel subdecurrentibus; stipite 30–70 × 3–6 mm., sursum pallide vinaceo, deorsum pileo concolori. Habitatio: inter muscos, locis ambustis autumnno. Washington et Oregon in America Boreali.

Pileus 1–3 cm. broad, obtuse with an inrolled margin when young, becoming obtusely campanulate to broadly convex in age, sometimes flattened but with a decurved margin, surface dry and covered with minute conic to subappressed granulate to fibrillose scales, often with only spotlike scales in age, color rusty vinaceous brown to deep sordid vinaceous ("sorghum brown" to "Vandyke brown"), sometimes dull chestnut brown to deep brick color, gradually fading in age and becoming avellaneous or merely a very sordid pale vinaceous brown; flesh whitish to pallid and unchanging, thin, moderately fragile, odor and taste not distinctive; lamellae close to subdistant, 30–38 reach the stipe, 2–3 tiers of lamellulae, broadly adnate to subdecurrent, broadest (3–4 mm.) near the stipe, whitish to pale buff and unchanging when bruised or dried, edges even; stipe 3–7 cm. long, 3–6 mm. thick at the apex, slightly enlarged downward, soon hollowed, at least in the lower portion, pallid within, surface fibrillose-furfuraceous up to a superior fibrillose annular zone, the fibrils pallid and at first forming an almost cortinate veil, sheath concolorous with the scales of the pileus and not breaking up into conspicuous zones or scales, composed of an outer deeply colored more or less furfuraceous layer and an inner pallid fibrillose layer, the latter becoming more conspicuous in age, apex silky and pallid vinaceous at first, when dried having a dull purplish-vinaceous cast.

Spores hyaline in KOH, nonamyloid,  $4\text{--}4.5 \times 2.5\text{--}3 \mu$ , ellipsoid,

basidia four-spored,  $18-20 \times 4-5 \mu$ ; pleurocystidia and cheilocystidia not differentiated, gill trama homogeneous, the hyphae parallel to subparallel, hyaline in KOH and dull yellowish tawny in iodine; pileus trama with a more or less differentiated cuticle, the cells on and near the surface more or less globose to ellipsoid and with dark to pale rusty-brown walls in KOH, the enlarged cells  $10-40 \times 10-20 \mu$ , beneath these occurs a gradual transition to a much-branched tangled mass of filamentous hyphae with rusty-brown walls, the trama proper not distinctly separated from this region (the color of the cell walls merely less intense progressively toward the gills), clamp connections present, the colored hyphae beneath the inflated cells  $5-10 (15) \mu$  in diameter.

*Habitat.* — Gregarious on moss beds of *Funaria* and *Ceratodon* in areas where brush has been burned, such as along roads and along the edges of fields. Fall.

*Distribution.* — The Olympic Peninsula of Washington, south into Oregon.

*Material studied.* — Smith, Lake Crescent, Washington, Oct. 10, 1935, 3081 (UM); McKenzie Bridge, Cascade Mts., Oregon, Oct. 14, 1937, 7787 (UM); the type, Heart O'Hills, Mt. Angeles, Olympic Mts., Washington, Sept. 28, 1941, 17382 (UM).

*Observations.* — This variety differs from var. *typicum* in its sub-decurrent gills, more vinaceous colors, and in the sheath of the stipe remaining more or less intact. In the field it would probably be confused with *C. haematites* because of the resemblance in color. The habitat may also be distinctive, but this needs verification from a larger number of collections. In the dried condition var. *typicum* and var. *occidentale* are almost inseparable, and old carpophores of both bleach in much the same manner if exposed to the weather for long periods.

(e) Var. **adnatifolium** (Peck), comb. nov.

*Lepiota adnatifolia* Peck, Bull. New York State Mus., 10: 947. 1902.

*Armillaria adnatifolia* Kauffman, Pap. Mich. Acad. Sci., Arts, and Letters, 2 (1922): 60. 1923.

Illustration: Figure 2, spores (p. 84).

Pileus 2.5-5 (8) cm. broad, ovoid to convex when young, expanding to broadly convex or plane, at times retaining an obtuse umbo, the margin appendiculate from the remains of the veil, surface

covered by more or less granulose pyramidal scales, scales crowded over the central portion and more widely separated toward the margin; scales either persistent or becoming worn down and somewhat powdery, color bright reddish orange ("English red" to "orange rufous"), surface between the scales paler reddish; flesh thick, at least in the disc, tapered toward the margin, white to pale ferruginous near the surface; lamellae crowded, adnate to slightly adnexed, narrow (3-5 mm.), whitish to pale buff, edges even; stipe 2.5-4 (7) cm. long, 5-10 mm. thick at apex, clavate, solid but at times hollowed in age, glabrous or slightly squamulose below the small often evanescent annulus, pallid or rufescent, silky above and pallid or tinged pale rufous tan.

Spores hyaline in KOH,  $3.5-4.4 \times 2.3-2.8$  (3)  $\mu$ , smooth, ellipsoid, nonamyloid; basidia  $16-18$  (20)  $\times 4-4.5$   $\mu$ , four-spored, hyaline in KOH; pleurocystidia and cheilocystidia none; gill trama hyaline in KOH, with an interwoven central strand flanked by parallel hyphae near the subhymenium, subhymenium very thin, filamentous, and much branched; pileus with a cuticle of chains of globose to subglobose cells, the cells readily separable and  $12-25 \times 10-20$   $\mu$ , the walls smooth or faintly rugulose and pale cinnamon in KOH (not deep reddish), subcuticular hyphae more or less filamentous (the change gradual), very pale cinnamon except for the layer giving rise to the chains of cells forming the cuticle, tramal body of hyaline hyphae 4-6.5  $\mu$  in diameter and with abundant clamp connections.

*Habitat.* — Scattered to gregarious under conifers. September and October. Rather uncommon.

*Distribution.* — Ontario, Maine, New York, Michigan, Wyoming, Idaho, Oregon, and Washington.

*Material studied.* — The following collections of fresh material have been studied: Mains, Harbor Springs, Michigan, Sept. 14, 1932, 32-760 (UM). Smith, Lake Timagami, Ontario, Sept. 5, 1936, 4554 (UM, University of Toronto Herbarium); Blue River, Oregon, Oct. 17, 1937, 7919 (FH, UM). The following collections of dried material were examined: Hotson, Washington (UW). University of Toronto Herbarium, 11884, coll. Roy F. Cain, York County, Ontario (UT). Kauffman, Lakeland, Michigan, Oct. 11, 1912 (UM); Lake Placid, Adirondack Mts., New York, Sept. 5, 1914, with Mains (UM); Pend d'Oreille, National Forest, Copeland, Idaho, Sept. 7, 12, 1922, with Wehmeyer (UM); Parlin, Canton Point, Maine, Oct. 25-29,

1942, 15332, 15333, 15334, 15402 (all UM). Peck, Hague, and Bolton, Warren County, New York, type (NYS). F-10554, Île Perrot, Quebec, Aug. 27, 1941 (MO); 11047, Petawawa Forest Experiment Station, Sept. 29, 1942 (MO); one unnumbered collection, Wakefield, Ontario, Aug. 12, 1903, as *L. granulosa* (MO).

*Observations.* — Since the material of the type collection, which was examined by the senior author, did not have cystidia, it became necessary to reclassify Peck's species as a variety of *C. granulosum*. The microscopic data in the description given above are taken from the type. Kauffman's account (1918) applies to *C. cinnabarinum*. The carpophores of var. *adnatifolium* dry a dull to bright orange, whereas those of var. *typicum* are nearer "mikado brown" to "chestnut brown" or, in f. *robustum*, "Verona brown." Var. *adnatifolium* is generally not so robust as *C. cinnabarinum*, but the colors are about the same. The presence of cheilocystidia at once distinguishes the latter.

#### KEY TO FORMS AND VARIETIES OF *C. GRANULOSUM*

##### I. Pileus 1-3 (4) cm. broad

- A. Pileus deep vinaceous brown ("sorghum brown" to "Vandyke brown"); gills typically subdecurrent ..... var. *occidentale*
- B. Pileus cinnamon, tawny to russet or yellowish; gills typically notched ..... var. *typicum*
- C. Pileus whitish or white ..... var. *typicum* f. *albidum*

##### II. Pileus 3-8 cm. broad

- A. Pileus "brick red" to "Hay's russet"; when dried dark sordid vinaceous cinnamon ("Verona brown") .... var. *typicum* f. *robustum*
- B. Pileus "English red" to "orange rufous," when dried pale orange ("apricot buff") ..... var. *adnatifolium*

### 3. *Cystoderma ponderosum*, sp. nov.

Illustration: Figure 3, spores (p. 84).

Pileo 4-11 cm. lato, squarroso-squamoso in disco e squamis ochraceo-alutaceis vel argillaceis vel laetius flavido-brunneis, squamis magis appressis sparsioribusque, interstitiis pallidis, textura squamarum vix granulosa, at subfibrillosa et squamis ex ea re satis persistentibus; carne crassa, albida vel pallida, odore et sapore haud notis; lamellis moderate confertis, angustis, late adnatis vel dente decurrentibus, pallide alutaceis, aciebus integris; stipite clavato, 60-80 × 8-15 mm., ad basin albomycelioideo, albo vel albido, sub-

tiliter et fugacissime cothurnato, mox vestimenti fractura zonatulo, zonis subconcoloribus squamis pilei, subfibrilloso supra annulum; sporis  $3-3.4 \times 2.6-3 \mu$ , late ellipsoideis vel subglobois, levibus, hyalinis; basidiis  $20-24 \times 4.6-6 \mu$ , tetrasporis; cystidiis nullis; textura tramali lamellarum ex hyphis parallelis vel intertextis efformata; carne KOH ope haud colorata, ex hyphis intertextis,  $4-6 \mu$  crassis, fibuligeris consistente; cuticula pilei ex hyphis  $4-6 \mu$  crassis, rubido-fulvis pigmenti incrustantis causa consistente, in squamis autem nonnullis hyphis inflatis praesentibus, at rarissime globosis vel ellipsoideis usque ad  $30 \times 15 \mu$  metientibus. Habitatio: ad terram muscosam supra saxum; Tennessee, America Borealis.

Pileus 4-11 cm. broad, broadly convex becoming plane, in age the margin wavy, lobed, uplifted in large carpophores in age, surface dry, squarrose-scaly over the disc from "ochraceous buff" to "clay color" or brighter yellowish-brown scales, toward the margin the scales more appressed and widely separated, allowing the pallid ground color to show, the scales more fibrillose than granulose in texture and consequently relatively persistent; flesh thick, whitish to pallid, odor and taste not recorded; lamellae moderately close, narrow, broadly adnate or with a decurrent tooth, near "light buff," edges even; stipe clavate, 6-8 cm. long, 8-15 mm. at the apex, base more or less white-mycelioid, white or whitish, the sheath thin and evanescent, soon broken up into small zones which are more or less concolorous with scales of pileus, annulus poorly formed and evanescent, somewhat fibrillose above the annulus, in largest carpophore distinctly fibrillose-pubescent to the apex, pubescence pallid buff.

Spores  $3-3.4 \times 2.6-3 \mu$ , broadly ellipsoid to subglobose, non-amyloid, smooth, hyaline in KOH; basidia  $20-24 \times 4.6-6 \mu$ , four-spored, hyaline in KOH, yellowish in iodine; pleurocystidia and cheilocystidia not differentiated; gill trama hyaline in KOH, parallel to interwoven; flesh of pileus hyaline in KOH, of compactly interwoven hyphae  $4-6 \mu$  in diameter, clamp connections abundant; cuticle of pileus composed chiefly of interwoven tawny to russet hyphae  $4-6 \mu$  in diameter and both very much branched and very compactly interwoven as compared with other species, the walls with incrusting pigment, the scales with a few enlarged cells present but these seldom spheric or ellipsoid, instead rather somewhat angular or otherwise irregular in shape, the largest about  $30 \times 15 \mu$ .

*Habitat.* — On mossy soil on rocks, Mt. Le Conte, Great Smoky



Mountains National Park, Tennessee, July 26, 1942, L. R. Hesler, 14390.

*Distribution.* — Known only from the type collection.

*Observations.* — When the scales of the pileus are crushed, all the cells appear to be broken from their attachment and hence cannot be regarded as readily separable as in related species. The color of *C. ponderosum* is very distinct in the dried specimens, though when mounted in KOH the cuticular and subcuticular hyphae of both *C. cinnabarinum* and *C. ponderosum* are quite similar in color, and the more compact arrangement present in the latter as well as the lack of sphaerocysts must be relied upon to distinguish it. Because of the difference in color of dried material it can readily be distinguished from all other species in the genus. This is the one species of *Cystoderma* that most closely approaches the section *Acutesquamosae* of the genus *Lepiota*. In fact, the structure of the cuticle, which is in the nature of trichoderms rather than an epithelium, recalls certain representatives of that section. However, the non-pseudoamyloid spores and the adnate lamellae cause us to consider *C. ponderosum* a true *Cystoderma*. The lack of cheilocystidia may serve as additional evidence that this species is not a *Lepiota*.

4. *Cystoderma cinnabarinum* (Alb. & Schw. ex Secr.) Fayod,  
Ann. Sci. Nat., Sér. 7, 9:351. 1889.

*Agaricus granulatus cinnabarinus* Alb. & Schw. ex Secretan, Mycogr. Suisse, 1:60. 1833.

*Agaricus (Lepiota) granulosa* subsp. *cinnabarina* Fries, Monogr. Hymen. Suec., 1:29 (13 in reprint). 1857.

*Agaricus cinnabarinus* Fries, Hymen. Eur., p. 36. 1874.

*Lepiota granulosa* var. *cinnabarina* Gillet, Les Hyménomycètes, p. 71. 1874.

*Lepiota granulosa* subsp. *cinnabarina* Konrad et Maublanc, Icon. Sel. Fung., Vol. III, pl. 238. 1924-33.

*Lepiota cinnabarina* Karsten, Hattsvampar, p. 14. 1879.

*Armillaria cinnabarina* Kauffman, Pap. Mich. Acad. Sci., Arts, and Letters, 2(1922):60. 1923.

Illustrations:

Figures 5-6, spores (p. 84).

Barla, Champ. Alp. Mar., pl. 16, figs. 1-4.

Boudier, Icon. Mycol., I, pl. 15 (? or *C. granulatum* var. *adnatifolium*).

Britzelmayer, Hymen., pl. 42, fig. 294.

Cooke, Illus. Brit. Fungi, no. 38, pl. 43.

Flora Danica, Fasc. 30 (1823), pl. 1795 (as *Ag. granulatus*).

Hoffmann, Icon. Anal., pl. 13, fig. 1.

Lange, Flora Agar. Danica, pl. 15, fig. F (excellent); also pl. 15, fig. E (as *L. granulosa*).

Pileus 3-6 (8) cm. broad, ovoid when young or at times more or less convex, expanding to broadly convex, sometimes plane or remaining broadly umbonate, surface dry and covered by numerous short-pointed pyramidal scales from the breaking up of the granulose cuticle, the scales fairly persistent and becoming rather widely separated over the marginal area in age as a result of the expansion of the pileus, margin appendiculate at first with fragments of the broken veil, color bright red to bright orange brown with the paler flesh showing between the scales ("English red," "cinnamon rufous" to "ferruginous") over the disc, usually paler over marginal area, sometimes "Sanford's brown" on the disc and "cinnamon rufous" on the margin; flesh thin, pallid or ferruginous near the surface, somewhat watery, odor oily-farinaceous; lamellae bluntly adnate but soon seceding and free, broadest next to the stipe but narrow in relation to the diameter of the cap, close to crowded, thin, white to creamy white, unchanging, edges even to minutely fimbriate; stipe 3-6 cm. long, (6) 8-15 mm. thick at apex, solid, more or less clavate-bulbous and with considerable débris and mycelium adhering to the base, sheathed up to the evanescent annulus with a furfureous to granulose sheath similar in color and texture to the scales covering the pileus, with an inner thin pallid fibrillose coating giving the stipe a coarsely fibrillose appearance if the outer colored layer becomes worn away, creamy buff to pale rufous above the annular zone and silky-fibrillose to somewhat pruinose, flesh pallid.

Spores white in deposits, nonamyloid,  $3.5-5 \times 2.2-3$  (3.4)  $\mu$ , smooth, ellipsoid; basidia  $16-24 \times 4-5.5 \mu$ , four-spored or occasionally very few one- to three-spored; pleurocystidia very rare to abundant,  $32-46 \times 4-9 \mu$ , basal portion slightly ventricose and tapered to a long narrow neck with a slightly enlarged almost spear-shaped apex which may or may not be slightly incrustated, hyaline and thin-walled; cheilocystidia scattered to abundant, similar to pleurocystidia, about  $2-3.5 \mu$  thick in the upper half; gill trama homogeneous, regular, subparallel at first, interwoven in fully expanded caps, hyaline in KOH, subhymenium not distinctive; pileus trama composed of a cuticle of globose ( $10-35 \mu$ ) and more or less elongated ( $30-50 \times 10-16 \mu$ ) cells, bright reddish brown in KOH, the walls smooth, beneath this layer a region of brown-walled filamentous hyphae, which gradually merges into the hyaline flesh toward the gills, clamp connections present.

*Habitat.* — Scattered to gregarious on decayed coniferous wood, on needle beds under various species of conifers, under hardwoods on humus, and among mosses such as *Rhizidium*. It fruits during the late summer and fall, and is fairly common.

*Distribution.* — This species is known throughout Europe and temperate North America. Singer has collected it in the Altai Mountains of Asia.

*Material studied.* — The following collections were studied in the fresh condition: Singer, A432, Kurai, July 31, 1937, coll. Singer and Vasilieva (L); Newcomb, New York, Huntington Wild Life Forest, Sept. 16-17, 1941, 99 (FH). Smith, Colchester County, Nova Scotia, Aug. 18, 1931, Wehmeyer, 779 (UM); Lake Crescent, Washington, Oct. 14, 1935, 3148 (UM); Joyce, Washington, Oct. 2, 1935, 2791 (UM); South Fork, McKenzie River, Oregon, Oct. 20, 1937, 7998 (UM); Belknap Springs, Oregon, Oct. 23, 1937, 8135 (UM); Crescent City, California, Oct. 30, 1937, 8253 (UM); Fort Dick, California, Nov. 10, 1937, 8594 (UM); Trinidad, California, Nov. 12, 1937, 8675 (UM); Crescent City, California, Nov. 29, 1937, 8979 (UM); Baker Lake, Washington, Sept., 1941, 16893 (UM).

Dried specimens have been examined as follows: Farlow, Shelburne, New Hampshire, Sept., 1891, as *Ag. granulatus*, dark red form (FH). Hotson, New Richmond Beach, Washington, Oct. 8, 1933 (UW). University of Toronto Herbarium, 9617, coll. H. S. Jackson, York County, Ontario, Canada, Oct. 4, 1936 (UT). Hesler, 14076, New Hopewell, Knox County, Tennessee, Nov. 26, 1941 (UT); 14117, Ball Camp Pike, Knox County, Tennessee, Dec. 19, 1941 (UT); 14354, Highlands, North Carolina, Sept. 3, 1942 (UM, UT); 15910, Claxton School, Anderson County, Tennessee, Oct. 17, 1943 (UT). Mains, 32-532, Au Train, Michigan, Sept. 3, 1932 (UM); 32-776, Harbor Springs, Michigan, Sept. 14, 1932 (UM); no number, Presque Isle County, Michigan, Sept. 13, 1935 (UM). Kauffman, Ithaca, New York, Aug. 9, 1902 (UM); Ann Arbor, Michigan, Aug. 27, 1905, as *L. granulosa* (UM); Marquette, Michigan, Aug. 27, 1906 (UM); Whitmore Lake, Michigan, Oct. 4, 1907 (UM); North Elba, New York, Sept. 10, 1914 (UM); Wassott, Wisconsin, Aug. 23, 1921, coll. L. Dosdall (UM); Mt. Hood, Oregon, Oct. 13, 1922 (UM); Lake Quinault, Washington, Sept. 14, 1925 (UM). Kelly, 983, as *L. amianthina*, det. Beardslee, Magnetawan, Ontario, Canada, Aug. 29, 1921 (UM); Magnetawan, Ontario, Aug. 23, 1924, as

*L. adnatifolia*, det. Kelly (UM). Walters, Cleveland, Ohio, Oct. 20, 1942 (UM). Zeller, 9172, Big Creek, Lincoln County, Oregon, Nov. 19, 1934 (UM, Z); same locality, Nov. 7, 1935 (UM, Z); 9304, 9305, Florence, Oregon, Nov. 23, 1935 (UM, Z).

The following collections are deposited in the Mycological Herbarium of the Department of Agriculture, Ottawa, Canada. F-5704, Mt. Burnet, Quebec, Sept. 30, 1934; F-6979, same locality, Sept. 13, 1936; F-7565, Eardly, Quebec, Sept. 22, 1937; F-7619, Chalk River, Ontario, Sept. 3, 1937; F-7874, Mt. Burnet, Quebec, Oct. 17, 1937; F-9592, Petawawa Forest Experiment Station; F-9627, In-golf, Ontario, Aug. 21, 1939; 11128, Petawawa Forest Experiment Station, Sept. 29, 1942.

*Observations.* — This species varies considerably in color from cinnabar red to reddish orange, with the result that it is likely to be confused with *C. granulosum* var. *adnatifolium* if one does not check for the presence of the cheilocystidia. The cystidia are irregular in their distribution, and at times both pleurocystidia and cheilocystidia are abundant, though usually only the cheilocystidia can be readily demonstrated. The relationship of *C. granulosum* var. *typicum* f. *robustum*, *C. granulosum* var. *adnatifolium*, and *C. cinnabarinum* needs further study. We have selected the most practical differences found, namely, the presence of cystidia, as the basis for recognizing *C. cinnabarinum* and *C. australe*. There are several color forms of *C. cinnabarinum* which should perhaps be given recognition. Since Konrad and Maublanc and Bresadola did not describe cystidia for the fungus they illustrated as *C. cinnabarinum* and since their plates do not show the brilliant colors typical of that species as we know it, we believe that their plates are properly referred to *C. granulosum* f. *robustum*.

### 5. *Cystoderma australe*, sp. nov.

Pileo circa 15 mm. lato, subplano, sicco, persistenter verruculoso- vel squarruloso-squamuloso, uniformiter ferrugineo-fusco, specimina obscuriora *Cystodermatis granulosi* in mentem revocante; carne tenui, pallida, odore saporeque haud notatis; lamellis confertis, latis, albis vel albidis ac paulum decolorantibus in siccitate, aciebus integris; stipite circa  $20 \times 2$  mm., curvato, pileo concolori vel vix fortius vinaceo-tincto, ad apicem sericeo, deorsum fibrilloso-squamuloso, annulo distincto destituto, zona velo rupto

relieta in medio stipitis vel infra. Sporis  $4-5.5(6.5) \times 2.7-3.4 \mu$ , anguste ellipsoideis, levibus, haud amyloideis, vel multis sporis conglomeratis vix pseudoamyloideis; basidiis tetrasporis,  $16-22 \times 5-6 \mu$ ; pleurocystidiis interdum praesentibus prope aciem lamellarum et tunc cheilocystidiis similibus; cheilocystidiis abundantibus, forma sua ea *Cystoderma cinnabarinum* in mentem revocantibus,  $12-21 \times 4-5.5 \mu$ , parte angustata  $1.5-4 \mu$  crassa; textura tramali lamellarum regulari, hyphis subintertextis, in KOH hyalinis; cuticula pilei ex hyphis ovoideis vel ellipsoideis vel elongatis vel subirregularibus, subcatenulatis consistente, membranarum hypharum harum levibus, subincrassatis, KOH ope luride ferruginascentibus; carne pilei ita ut hyphis subcuticularibus in medio alcalino (KOH) hyalinis, laxis, septis fibuligeris. Habitatio: ad ligna putrescentia arborum frondosarum Floridae meridionalis.

Pileus about 15 mm. broad, nearly plane with a wavy elevated margin, surface dry and covered with small wartlike or pointed persistent scales, evenly dark rusty brown over all ("Verona brown" when dried), the colors similar to those of dark specimens of *C. granulatum* and both assuming the same color in drying; flesh thin, pallid, odor and taste not recorded; lamellae close, broad, adnate, white or whitish and only slightly discolored in drying, edges even; stipe about 20 mm. long, 2 mm. thick, curved, tinged with the color of the pileus or slightly more vinaceous, silky above, lower portion fibrillose-scaly with small scales similar in color to those of the pileus, no distinct annulus present, the zone left by the broken veil median or slightly lower.

Spores  $4-5.5(6.5) \times 2.7-3.4 \mu$ , narrowly ellipsoid, smooth, non-amyloid or in mass slightly pseudoamyloid; basidia four-spored, hyaline in KOH, subcylindric to narrowly clavate,  $16-22 \times 5-6 \mu$ ; pleurocystidia if present near the gill edge and similar to cheilocystidia; cheilocystidia abundant, similar in shape to those of *C. cinnabarinum*,  $16-22 \times 4-6 \mu$ , the narrowed portion  $1.5-4 \mu$  thick; gill trama regular, the hyphae slightly interwoven, hyaline when revived in KOH; cuticle of pileus of ovoid to ellipsoid or elongated to somewhat irregularly shaped cells loosely arranged in chains, sphaerocysts not numerous, the walls smooth, slightly thickened and dull rusty brown in KOH; flesh of pileus including subcuticular hyphae hyaline or nearly so in KOH, hyphae loosely arranged, clamp connections abundant.

*Habitat.* — Solitary on a decayed log on the ground.

*Distribution.* — Known only from the type collection, Singer, F-1184, Matheson Hammock, Dade County, south Florida, Oct. 22, 1942 (FH).

*Observations.* — Although this species has the same type of cheilocystidia as *C. cinnabarinum*, it is readily distinguished by its habitat on decaying nonconiferous logs, its southern distribution, the color of the pileus, and the stature of the carpophore. This combination of characters cannot be disregarded. From *C. granulorum*, in which it was placed at the time of its collection, it can readily be distinguished not only by its characteristic cheilocystidia but also by the difference in the coloring of the subcuticular hyphae in KOH. In *C. australe* the reaction is not much stronger than that found in *C. amianthinum* var. *typicum*; in other words, it is almost lacking.

#### 6. *Cystoderma rhombosporum* (Atkinson), comb. nov.

*Lepiota rhombospora* Atkinson, Proc. Am. Phil. Soc., 57: 356. 1918.

*Armillaria rhombospora* Kauffman, Pap. Mich. Acad. Sci., Arts, and Letters, 4 (1924): 317. 1925.

Illustrations: Figures 4, 7, spores and cheilocystidia (p. 84).

"Gregaria vel solitaria, 3-4 cm. alta: pileo convexo, 8-15 mm. lato, 1 cm. alto, adolescente ochraceo-fulvo, demum ochroleuco granuloso et squamuloso: squamulis cellis rotundatis vel obovatis vel pyriformibus praeditis: lamellis stipite adnatis vel adnaxis, sinuatis, ventricosis, argillaceis: cystidiis solum in acie lamellarum, lanceoideis,  $24-32 \times 6-8 \mu$ ; sporis quaternis, bilateralibus, albis, a fronte rhomboideis et utrimque acutiusculis, a latere inequilateralibus, levibus,  $4-5 \times 3-4 \mu$ : stipite aequali, pileo concolore, granuloso et squamuloso.

"Nos. 24323 and 24324, type. C. U. Herb."

The original description has been quoted. The following microscopic data were obtained from Atkinson's collection, 24324: Spores  $5-6 \times 3.8-4.5 \mu$ , subrhomboid to ventricose-apiculate, smooth, non-amyloid, hyaline in KOH when isolated, very faintly though distinctly tinged cinnamon when seen in groups on the faces of the gills; basidia  $16-18 \times 5-6 \mu$ , four-spored, hyaline in KOH, pale yellow in iodine; pleurocystidia not seen; cheilocystidia abundant,  $26-38 \times 5-7 \mu$ , narrowly fusoid-ventricose or some subcylindric with an abruptly narrowed elongated flexuous apical proliferation, hyaline

in KOH, yellow in iodine, thin-walled (when groups are viewed in KOH the bases of some appear pale cinnamon, but this was not evident on isolated cystidia); gill trama regular, of parallel long narrow hyaline hyphae, subhymenium very thin and not distinctive, pale yellow in iodine; pileus trama with a cuticle of ellipsoid to globose cells  $12-30 \times 10-18 \mu$ , arranged in chains, the cells readily separating from one another, some clavate cells borne on narrow pedicels also present in the layer and occasional scattered filamentous hyphae also present, when revived in KOH the cuticular cells smooth, tawny to pale tawny, and with minute pores extending through the wall; subcuticular hyphae filamentous and hyaline or only faintly yellowish in KOH; flesh proper hyaline or tinged pale cinnamon in KOH, of compactly interwoven hyphae, clamp connections present.

*Habitat.* — Solitary to gregarious in the edge of mixed woods on leaf mold. By Stewart's Camp, Seventh Lake, Adirondack Mountains, New York. August.

*Distribution.* — The distribution of this rare species remains to be established. At present it is known only from the type locality.

*Material studied.* — Atkinson, 24324 (CU).

*Observations.* — This species is readily distinguished from all other members of the genus by the shape of its spores. They resemble those of some species of *Tubaria*. Since the deposit was described as white, we are not inclined to place much emphasis at present on the very slight coloration observed in the spores adhering to the hymenium, but when the species is re-collected, efforts to get good spore deposits on white paper should be made in order to check the possibility of a creamy or slightly more yellowish tint being present. It is possible that *C. rhombosporum* is a connecting link with the genus *Naucoria*. We have retained it here in *Cystoderma* because the spore wall is very thin and typical for the genus, and its color is by no means so distinct as it is in even the pale-spored *Naucoriae*. In addition, the cuticular cells of the pileus do not have an incrusting pigment.

SECTION II: AMIANTHINA A. H. SMITH  
AND R. SINGER, SEC. NOV.

*Sporis amyloideis*.

7. *Cystoderma carcharias* (Pers. ex Secr.) Fayod,  
Ann. Sci. Nat., Sér. 7, 9:351. 1889.

*Agaricus granulosus* d Fries, Syst. Mycol., 1: 25. 1821.

*Agaricus carcharias* Pers. ex Secretan, Mycogr. Suisse, 1: 62. 1833.

*Agaricus granulosus* var. *carcharias* Fries, Epicr. Syst. Mycol., p. 18. 1836.

*Agaricus granulosus* subsp. *incarnato-albida* Fries, Monogr. Hymen. Suec., 1: 29 (13 in reprint). 1857.

*Lepiota granulosa* var. *carcharias* Gillet, Les Hyménomycètes, p. 71. 1874.

*Lepiota carcharias* Karsten, Hattsvampar, p. 14. 1879.

*Armillaria carcharias* Kauffman, Pap. Mich. Acad. Sci., Arts, and Letters, 4 (1924): 317. 1925.

## Illustrations:

Fig. 9, spores (p. 84).

Barla, Champ. Alp. Mar., pl. 15, figs. 16-18.

Bigéard et Guillemin, Champ. Suppl. Fr., p. 53, pl. 11, fig. 5.

Boudier, Icon. Mycol., Vol. I, pl. 14.

Bresadola, Icon. Mycol., Vol. I, pl. 38.

Briganti, De fungis rarioribus regni neapolitani historia, pl. 17, figs. 4-7.

Britzelmayr, Hymen., pl. 34, fig. 135 (*L. carcharias* f. *isabellina*, pl. 158, fig. 744).

Cooke, Illus. Brit. Fungi, no. 37, pl. 42.

Krombholz, Naturgetreue Abbildungen und Beschreibungen der essbaren, schädlichen und verdächtigen Schwämme, pl. 25, figs. 21-25.

Lange, Flora Agar. Danica, Vol. I, pl. 15, fig. D.

Lucand, Figures peintes des Champignons supérieures de la France, pl. 202.

Persoon, Icon. Fung., pl. 5, figs. 1-3.

Ricken, Die Blätterpilze, Vol. II, pl. 82, fig. 3.

Voglino, Nuovo giorn. bot. ital., 19 (1887), pl. 7, fig. 8.

F. *typicum*

Pileus 2.4-4 cm. broad, obtuse to convex when young, expanding to plane or often remaining umbonate, surface dry and covered with very minute to medium-sized granules, pale lilaceous to pallid flesh color, pale sordid tan when dried, the margin often denticulate from the remains of the broken veil; flesh whitish to ochraceous, odor unpleasant, mawkish, taste disagreeable; lamellae adnate to slightly adnexed, white or pallid whitish, moderately broad, close; stipe 3-6 cm. long, 4-8 mm. thick, subbulbous and gradually narrowed upward, apex white to pallid but in age becoming sordid brownish flesh color, granulose and more or less concolorous with the pileus



below the superior annulus, in age also becoming sordid brownish flesh color; annulus well developed and flaring at first, granulose on under side, eventually collapsing and sometimes evanescent; surface of pileus olive yellowish to dirty alutaceous in KOH.

Spores white in deposits, (3.6)  $4.5-5.5 \times 3.2-3.9 \mu$ , distinctly but moderately strongly amyloid, ellipsoid, with a hilar applanation, not depressed, hyaline, smooth; basidia  $16-28 \times 5-6.4 \mu$ , four-spored; pleurocystidia and cheilocystidia not differentiated; gill trama hyaline and regular; pileus trama with a cuticle of enlarged to more or less globose cells readily becoming detached from one another, the cells  $11.5-35 \times 11-22 \mu$ , hyaline in KOH; subcuticular layer also hyaline in KOH, all hyphae with clamp connections.

*Habitat.* — Scattered to gregarious under pines and spruce, among mosses or fallen needles or on soil, July to November. Rare in North America; not uncommon in Europe.

*Distribution.* — Europe and possibly North America. In Europe it is known from all the larger countries, and its pattern of distribution covers the entire continent. In the United States it appears to be very rare and is doubtfully known from New York and Idaho.

*Material studied.* — Fresh material was studied by Singer from various places in Czechoslovakia, Austria, and Germany, 1923-31, and from Peterhof, Leningrad region, U.S.S.R., 1937 (L). The following collections of dried specimens have been examined: Hoehnel, two collections from Tullnerbach, Wienerwald, Austria (FH, in Hoehnel Herb.); Bresadola, Italy (FH). France, Patouillard Herb., ex Herb. Sarazin (FH), as *L. granulosa* var. *carcharias*, Nov., 1886; Germany, Allescher and Schnabl, *Fungi Bavarici*, 235. United States, Kauffman, Seventh Lake, Adirondack Mts., New York, Sept. 1, 1921, as *L. rugosoreticulata*, the identification doubtful.

*Observations.* — Two fruiting bodies which appeared to belong in this species were found near the Lake Fork Ranger Station, Idaho National Forest, Idaho, but were unfortunately lost in drying, so that the microscopic details could not be rechecked from the dried specimens. Actually the occurrence of f. *typicum* in North America is not too well established. Singer, who has studied the Kauffman material, expressed doubt as to its identity but at the same time admitted that no other disposition was as satisfactory. No record was made of the KOH reaction of the cuticle on the Idaho collection before it was lost.

*F. album* (Fr.), comb. nov.

*Agaricus carcharias* var. *B* Secretan, Mycogr. Suisse, I: 62. 1833.

*Agaricus carcharias* var. *alba* Fries, Hymen. Eur., p. 36. 1874.

*Lepiota carcharias* var. *alba* Saccardo, Syll. Fung., 5: 46. 1887.

Illustrations:

Plate II.

Harzer, Naturgetreue Abbildungen der Pilze, pl. xlv, fig. B (as *Ag. cristatus*).

Pileus 1–3.5 cm. broad, convex or with a slight umbo, sometimes obtusely conic, surface dry and densely covered with small granulose warts or scales or with a more or less even powdery covering when the scales have been worn or broken down, surface even or slightly radially rugose, color white to whitish, becoming "cartridge buff" at times, margin noticeably appendiculate with submembranous patches of the broken veil, the outer side of the patches bearing small powdery scales similar to those on the pileus; flesh white, thick on the disc, thin toward the margin, firm, dry; lamellae close, 35–39 reach the stipe, broad (3 mm.), broadly adnate, slightly but sharply adnexed, white, edges crenulate; stipe 5–7 cm. long, 2.5–3 mm. thick, equal above a base enlarged by adhering white mycelium and débris, increasingly granulose-scaly up to the apical submembranous annulus, white and silky above, glabrescent and merely faintly powdery in age, stuffed, concolorous with the pileus at all stages; annulus with powdery scales on under side, upper surface silky.

Spores 4–5 × 3  $\mu$ , hyaline, ellipsoid, smooth, amyloid; basidia four-spored, 20–24 × 4–5  $\mu$ ; pleurocystidia and cheilocystidia not differentiated; gill trama homogeneous, its hyphae parallel to subparallel, hyaline in KOH, yellow in iodine; pileus trama homogeneous beneath a surface layer of globose thin-walled hyaline cells 20–35  $\mu$  in diameter, hyaline in KOH, yellowish in iodine, clamp connections present on the filamentous hyphae of pileus and gill trama.

*Habitat.* — Gregarious under conifers. Late summer and fall. Rare.

*Distribution.* — Europe and North America.

*Material studied.* — Smith, 11091, from under Norway pine (*Pinus resinosa* Ait.), Ogemaw State Forest, Midland, Michigan, Sept. 25, 1938 (FH, UM).

*Observations.* — This collection was originally referred to *A. Ambrosii* Bresadola (see Smith, 1942), but the occurrence of a very similar fungus in Oregon having nonamyloid spores and more lacerate

than granular scales on the stipe throws doubt on the identification. Since it is now impossible to obtain data on Bresadola's type, the greatest emphasis is here placed on the more lacerate scales of the stipe in the Oregon collection, and since this character is in line with Bresadola's description, the western collection is here identified as *C. Ambrosii*. The Ogemaw Forest collection differs from pale forms of *C. amianthinum* in the reaction of the cells of the cuticle in KOH.

### 8. *Cystoderma pulveraceum* (Peck), comb. nov.

*Lepiota pulveracea* Peck, Ann. Rep. New York State Mus., 54: 144. 1901.

*Armillaria pulveracea* Kauffman, Pap. Mich. Acad. Sci., Arts, and Letters, 4 (1924): 317. 1925.

Pileus 1–2.5 cm. broad, hemispheric becoming convex or nearly plane, dry, pulverulent or minutely granulose and squamulose, even on the margin, whitish or pallid inclining to tawny ("pinkish buff" to "Sayal brown" in herbarium specimens); lamellae thin, close, adnexed, yellowish white; stipe 2.5–5 cm. long, 3–4 mm. thick, equal to slightly clavate, hollow, white and pruinose at the apex, granulose or squamulose below the obsolete annulus and there colored like the pileus.

Spores  $4-4.5 \times 2.2-2.4 \mu$ , ellipsoid, amyloid, smooth, hyaline in KOH; basidia four-spored,  $14-16 \times 3-4 \mu$ , hyaline in KOH, yellow in iodine (the hymenium often pale to bright rusty yellow brown in iodine); gill trama parallel to subparallel, hyaline in KOH, yellow in iodine, subhymenium very thin and indistinct; pileus trama of hyaline filamentous hyphae (in KOH), compactly interwoven, clamp connections present; cuticle of pileus made up of globose to ellipsoid cells borne in chains which soon break up into the component cells, the latter  $10-18 (22) \mu$  in diameter, or if ellipsoid up to  $40 \mu$  long, some cylindric cells present (more than in *C. amianthinum*), many cells furnished with a flexuous proliferation from the apex, the walls thin and hyaline when revived in KOH or only very faintly yellowish, the subcuticular layer well developed and of hyaline much-branched hyphae  $6-8 \mu$  in diameter.

*Habitat.* — Single to scattered on old conifer logs. August and September. Rare.

*Distribution.* — New York and Michigan. Known only in North America.

*Material studied.* — Peck, Floodwood, August (NYS); Kauffman,

Marquette, Michigan, Sept. 2, 1906, on a rotten hemlock log, ex Herb. Kauffman, 507 (UM); North Elba, New York, Sept. 4, 1914 (UM).

*Observations.* — The microscopic data were obtained from Kauffman's North Elba collection. *C. pulveraceum* is most closely related to *C. subvinaceum* and *C. caucasicum*. It is readily distinguished from the former by its paler colors in the fresh condition and by the KOH reaction in herbarium material. From the latter it can be differentiated by the negative reaction with alkaline solutions of the cuticle of the pileus. The habitat and poorly formed annulus distinguish it from the white form of *C. carcharias*.

### 9. *Cystoderma caucasicum* Singer, sp. nov.

Pileo 10–13 mm. lato, convexo, demum margine plano, disco saepe subumbonato, albido, squamulis punctiformibus discum versus densioribus et obscurioribus tecto; carne alba; lamellis adnexis vel adnatis, confertissimis vel confertis, latissimis (2–3 mm.) in tertia parte marginali, ventricosis, brunnescentibus, atro-fuscis ad aciem in siccitate; stipite brevi, 12–14 × 2–3 mm., solido, subaequali vel basin versus attenuato, albido, infra annulum appressum, exiguum, persuperum fusco-squarruloso, supra annulum subcaesio-sordido; sporis 4 × 2.5  $\mu$ , ellipsoideis, fortiter amyloideis; basidiis 20–25 × 4–4.5  $\mu$ , tetrasporis; cystidiis nullis; textura tramali lamellarum subirregulari; hyphis carnis hyalinis; cellulis epithelii brunneolis vel hyalinis in medio ammoniacali; hyphis epithelii stipitis frequentius catenulatis quam in pileo. Habitatio: ad ligna putrida *Abietis Nordmannianae* in silvis mixtis montium Caucasi Occidentalis.

Pileus 10–13 mm. broad, convex, the margin finally spreading and horizontal, in age frequently becoming lobed, disc often remaining slightly and obtusely umbonate, whitish, the punctiform granular scales becoming more crowded toward the disc, darker than the ground color when the caps are dried; flesh whitish; lamellae adnexed to adnate, crowded to close, broadest (2–3 mm.) toward the margin of the pileus and ventricose, brownish when dried, deep bay at the edges in herbarium material; stipe short, 12–14 mm. long, 2–3 mm. thick, solid, subequal or tapering downward, whitish with brown erect scales, which leave the apex uncovered and naked and form a whitish appressed small annulus just below the apex, somewhat caesious-sordid at apex.

Spores  $4 \times 2.5 \mu$ , hyaline, thin-walled, entirely regularly ellipsoid, strongly amyloid, smooth; basidia  $20-25 \times 4-4.5 \mu$ , four-spored; pleurocystidia and cheilocystidia none; subhymenium subcellular, consisting of small cells of about  $3.5 \mu$  in diameter; trama of gills rather irregular, consisting of hyphae  $9 \pm \mu$  in diameter, which are frequently short-celled; flesh of pileus consistently of subparallel but variable cells up to  $14 \mu$  in diameter and hyaline ( $\text{NH}_4\text{OH}$ ); epithelium formed of short-ellipsoid to globose vesiculose cells, some with brownish content and some remaining colorless in  $\text{NH}_4\text{OH}$ , the walls moderately thickened ( $0.8 \mu$ ); the epithelium of the stipe similar but the cells more often connected in chains.

*Habitat.* — On decayed wood of *Abies Nordmanniana* Spach in mixed woods of beech and fir; elevation 700 meters.

*Distribution.* — Known only from the type locality near Guseripl, West Caucasus, Caucasus Mts., U.S.S.R.

*Material studied.* — The type (L).

*Observations.* — This material was first identified and published as *C. echinella* (Quél.) Singer apud Vasilieva, *Uchenye zapiski Kazansk. Universiteta*, 105(99): 56. 1939. Quélet's species, however, is described as having free gills, as growing on the ground, and with spores  $6-7 \times 3-3.5 \mu$ . Further consideration of these characters in the light of the information brought together here on *Cystoderma* indicates that the fungus in question is a previously undescribed species. It appears to be most closely related to *C. pulveraceum*, but is readily distinguished by the dissolved brownish pigment in at least some of the cells of the epithelium.

10. *Cystoderma amianthinum* (Scop. ex Fr.) Fayod,  
Ann. Sci. Nat., Sér. 7, 9: 351. 1889.

*Agaricus granulatus* subsp. *amianthinus* Fries, Epicr. Syst. Mycol., p. 18. 1836.

*Agaricus granulatus* subsp. *subochracea* Fries, Monogr. Hymen. Suec., 1: 29 (13 in reprint). 1857.

*Agaricus amianthinus* Scop. ex Fries, Hymen. Eur., p. 37. 1874.

*Lepiota granulosa* var. *ochracea* Gillet, Les Hyménomycètes, p. 71. 1874.

*Lepiota amianthina* Karsten, Hattsvampar, p. 15. 1879.

*Armillaria amianthina* Kauffman, Pap. Mich. Acad. Sci., Arts, and Letters, 2(1922): 60. 1923.

? *Armillaria muscicola* Cleland, Trans. and Proc. Roy. Soc. South Australia, 51: 299. 1927.

Illustrations:

Figure 11, spores (p. 84).

Barla, Champ. Alp. Mar., pl. 16, figs. 9-11.

- Batsch, Elench. Fung., fig. 97 (as *Ag. flavo-floccosus*).  
 Bolton, History of Funguses Growing about Halifax, pl. 51, fig. 2 (as *Ag. croceus*).  
 Boudier, Icon. Mycol., Vol. I, pl. 16.  
 Bresadola, Icon. Mycol., Vol. I, pl. 37.  
 Britzelmayer, Hymen., pl. 42, fig. 295.  
 Bulliard, Herbar de la France (Histoire des Champignons de la France), Vol. III, pl. 362; Vol. IV, pl. 530, fig. 3 (as *Ag. ochraceus*).  
 ? Cleland, Toadstools and Mushrooms of South Australia, Part I, fig. 10 (as *A. muscicola*).  
 Cooke, Illus. Brit. Fungi, no. 40, pl. 213, lower figures (very poor and possibly applying to a true *Lepiota*).  
 Doassans et Patouillard, Les Champignons figurés et desséchés, no. 18.  
 Farlow and Burt, Icones Farlowianae, pl. 10, lower figures (as *L. granulosa*).  
 Flora Danica, Fasc. 17 (1790), tab. 1015, fig. 2 (as *Ag. muricatus*).  
 Greville, Cryptog. Flora, 2, pl. 104 (as *Ag. granulosa*).  
 Harzer, Naturgetreue Abbildungen der Pilze, pl. 4, fig. 2.  
 Hoffmann, Icon. Anal. Fung., pl. 13, fig. 1 (as *Ag. granulosa*).  
 Hotson, Mycologia, 32: 785. 1940, fig. 1.  
 Hussey, Illus. Brit. Mycol., Vol. I, pl. 45.  
 Krombholz, Naturgetreue Abbildungen und Beschreibungen der essbaren, schädlichen und verdächtigen Schwämme, pl. 1, fig. 12 (as *Ag. granulosa*).  
 Lange, Flora Agar. Danica, pl. 15, fig. C.  
 Lanzi, Fungi di Roma, pl. 110, fig. 1.  
 Murrill, Mycologia, Vol. VII, pl. 158, fig. 5.  
 Patouillard, Tab. Anal. Fung., fig. 610.  
 Ricken, Die Blätterpilze, Vol. II, pl. 81, fig. 4.  
 Sicard, Hist. Nat. Champ., pl. 18, fig. 24.  
 Sowerby, Colored Figures of English Fungi or Mushrooms, pl. 19 (as *Ag. croceus*).

(a) Var. *typicum* f. *typicum*

Pileus (1.5) 2–3.5 (4.5) cm. broad, obtuse to convex, expanding to broadly convex or at times remaining obtuse, sometimes obtusely umbonate, the margin at first beautifully appendiculate with the more or less triangular flaps of tissue left by the broken veil, surface even to somewhat radially rugulose, dry and granulose, the granules aggregated into small spotlike scales which are more crowded on the disc, when young usually “buckthorn brown” (dull to rather bright ochraceous brown) on the disc and “antimony yellow” (pale yellow) toward the margin, finally “tawny” to “ochraceous tawny” or “yellow ocher” to almost “raw sienna” over the disc and paler (between “chamois” and “honey yellow”) toward the margin, becoming deep fulvous ferruginous with ammonia or KOH; flesh white or whitish, thin except in the disc, odor disagreeable, mawkish or not distinctive, taste mild; lamellae moderately close to crowded, about 2 tiers of lamellulae, moderately broad (2.5–3.5 mm.), squarely adnate at

first but often developing a tooth and becoming somewhat sinuate, white or whitish but usually pale orange yellow at maturity (sometimes "warm buff"), edges even; stipe 2.5–6 cm. long, 2–7 mm. thick at apex, equal or very slightly enlarged downward, solid, often becoming hollow, pith pallid, usually becoming brownish in age in the lower portion, surface sheathed with a granulose sheath up to the median to superior evanescent annulus, granulose portion concolorous with the pileus, pallid to yellowish and pruinose above the annulus, base with adhering white mycelium; annulus usually poorly formed and evanescent, tawny and granulose on outer or under side, and pallid and silky on upper or inner side if well formed.

Spores narrowly ellipsoid, hilar depression slight or lacking, (4.2) 4.5–6.5 (7.5)  $\times$  (2) 2.8–3.5  $\mu$ , distinctly though not always strongly amyloid, hyaline in KOH; basidia 21–28  $\times$  5.5–7  $\mu$ , clavate, four-spored, hyaline in KOH, yellow in iodine; cheilocystidia absent or when present very rare, 26–34  $\times$  5–7  $\mu$ , narrowly ventricose with obtuse apices; pleurocystidia not seen; gill trama regular, parallel or the central portion becoming somewhat interwoven, hyaline in KOH, yellowish in iodine; pileus trama with a cuticle composed of chains of globose to ellipsoid cells 18–48 (60)  $\times$  10–24 (40)  $\mu$ , their walls smooth to very faintly rugulose and rusty cinnamon color when revived in KOH, the chains readily breaking up into the component cells, very few narrowly ellipsoid to subcylindric cells present in the cuticle, tramal body of hyaline nonamyloid loosely interwoven hyphae, the subcuticular filamentous hyphae hyaline to only slightly pigmented, clamp connections present.

*Habitat.* — Single to densely gregarious among mosses, frequently on beds of *Polytrichum*, on fallen leaves in mixed woods, or on needle carpets under conifers. It fruits during the late summer and fall. In regions like California it appears during the winter rainy season. Rather common.

*Distribution.* — It is known from Europe, Asia, and North America, and probably South Australia. We have not examined material from either Japan or South Australia. Imai (1938) reported it from Japan, and Cleland has described under the name *Armillaria muscicola* what appears to be this species from South Australia. In North America it is known from Quebec and Ontario in Canada, and across the United States from Maine to Washington and south to North Carolina in the East and California in the West.

**Material studied.** — The following collections of fresh material have been studied: Singer, 129a (FH), 129c (FH) from New York; 107 (L), 108 (L), 200 (L), 200a (L), 200b (L), 372 (L), all from the Altai Mts. of Asia. E. B. and E. E. Mains, 32-544 (UM); Smith, 33-984 (UM) from Michigan; 493 (UM) from New York; 3839 (UM) from California. Hesler and Smith, University of Tennessee 11292, North Carolina (UM, UT). Smith, 7816 (UM) from Oregon; 17271 (UM) from Washington. The following collections of dried material have also been examined: Allescher and Schnabl, Fungi Bavarici, 234 (FH). Simon Davis, Massachusetts, 19110 (UM). Ellis and Everhardt, North American Fungi, 2001 (UM), as *Ag. (Lepiota) granulatus*. Farlow, Shelburne, New Hampshire, Sept., 1891 (FH) as *Ag. granulatus*. Flett, Bremerton, Washington, Feb. 10, 1940 (FH, UM). Groves, Norway Bay, Quebec (UM). Gruber, 13-7, Canyonville, Oregon, Nov. 27, 1942 (UM). H. Hotson, Washington, Oct. 16, Nov. 5, 1939, and Stuntz, Washington, 391, 395, 496 (UW). Hesler, University of Tennessee Herbarium, 8086, 8437, 14773, 15971 (all UT). Hesler, New Hopewell, Nov. 14, 1937 (FH), as *L. granulosa*. Jossierand, Oct. 7, 1937, near Lyon, France (FH, UM). Kauffman, Ithaca, New York, Aug. 19, 1904 (UM), as *L. granulosa*; North Elba, New York, Sept. 3, 1914 (UM); Lake Cushman, Olympic Mts., Washington, Oct. 6, 1915 (UM); Elkmont, Tennessee, Sept. 14, 1916 (UM), as *L. adnatifolia*; Lake Quinault, Washington, Oct. 17, 1925 (UM). Mains, 34-17 (UM) and 34-189 (UM), both from near Marquette, Michigan. Parlin, Canton Point, Maine, 15192, 15202 (UM). France, Sarazin Herb. in Patouillard Herb. (FH). Zeller, Lebanon, Oregon, 7800 (UM, Z). The following collections are deposited in the Mycological Herbarium of the Department of Agriculture at Ottawa, Canada: F-5717, Ingolf, Ontario (Manitoba boundary), Lange and Bisby, Sept. 17, 1931; F-8595, Laurentian National Park, Quebec, Aug. 27, 1938; F-8665, Burnet, Quebec, Sept. 25, 1938; 11427, 11557, Petawawa Forest Experiment Station, Ontario, Sept., 1943.

**Observations.** — Because of the confusion which has existed in regard to the identity of this species nearly all reports in the literature need to be verified by a study of the specimens on which they are based. Obviously we have not been able to do this. However, the species is common and widely distributed throughout temperate and northern regions. The spores are variable in length in the typical



variety, and this may lead to some confusion in the recognition of the other varieties, particularly var. *sublongisporum*. For a discussion of the differences between these two see page 114. According to our experience, *C. amianthinum* is much more frequently collected in the field than *C. granuloseum*, with which it has been mostly confused. The somewhat ventricose cheilocystidia appear to be too rare to help much in identifying *C. amianthinum*. In one collection, Hesler, Nov. 14, 1937 (FH), basidium-like bodies were found near the gill edges; they had thick walls and were without sterigmata or were characterized by one, two, three, or four sterigma-like projections. We have had no opportunity to study them on fresh material and cannot be sure whether they do or do not bear spores. They show up best when mounts are revived in the chloral-hydrate solution used to test the iodine reaction of the spores.

(b) Var. *typicum* f. **rugosoreticulatum** (Lorinser),  
comb. nov.

*Agaricus rugosoreticulatus* Lorinser, Oest. Bot. Zeitschr., 29: 23. 1879.

*Lepiota rugosoreticulata* Saccardo, Syll. Fung., 9: 10. 1891.

*Armillaria rugosoreticulata* Zeller, Mycologia, 33: 378. 1933.

Illustration: Plate III.

Pileus (2)3-5.5 cm. broad, obtusely conic when young, becoming obtusely umbonate to convex or plane, surface dry and granulose, conspicuously radially rugose or reticulate, color evenly dull yellowish brown to ochraceous brown ("buckthorn brown") or brighter, the margin at first strikingly appendiculate with fragments of the veil; flesh thin, whitish, odor disagreeable to lacking, taste not distinctive; lamellae bluntly adnate, close, narrow, white to whitish, edges even; stipe 4-8 (9) cm. long, 3-8 mm. thick, equal to slightly enlarged either way, stuffed with a white pith, granulose and concolorous with pileus up to the evanescent annulus or with zones or patches of granulose tissue if sheath is broken, smooth above the annulus, apex minutely pruinose and whitish; annulus superior, evanescent, concolorous with pileus and granulose on outer (under) side and smooth and pale buff on the upper side, often ragged and poorly formed.

Spores 5-6 (7.5)  $\times$  3  $\pm$   $\mu$ , amyloid, narrowly ellipsoid, smooth, hyaline, white in mass; basidia four-spored, 18-20  $\times$  5-6  $\mu$ , hyaline in KOH, yellowish in iodine; cheilocystidia and pleurocystidia not

differentiated; gill trama subregular to interwoven, the cells more or less cylindric in freshly matured carpophores,  $18-80 \times 6-9$  (12)  $\mu$ , subhymenium not distinctive; pileus trama with a differentiated cuticle of globose to inflated saccate cells  $12-40 \times 10-30 \mu$ , originating in chains and having smooth tawny-brown walls when revived in KOH, the layer of irregular thickness and very few elongated to cylindric colored cells present, trama beneath the cuticle of hyaline interwoven hyphae, clamp connections present.

*Habitat.* — Scattered to gregarious on soil, beds of moss, or mats of conifer needles. Its fruiting period coincides with that of *f. typicum*.

*Distribution.* — It is to be expected throughout the range of *f. typicum*. It is known from both Europe and North America. We have examined North American material from North Carolina, Tennessee, Michigan, California, Oregon, and Washington.

*Material studied.* — Fresh fruiting bodies from the George Reserve, Pinckney, Michigan, Smith, 7044 (UM); Lake Crescent, Washington, 3082 (FH, UM); California, 8713 (UM); and Tennessee, Hesler and Smith, 9875 (UM) have been studied. The photograph and description were taken from collection 3082. The following collections of dried material have been examined: Gruber, 20-6, Mt. Scott, Portland, Oregon, Dec. 14, 1942. Hotson, Washington, Oct. 16, 1934 (UW). Hesler, 9590, 12296, 12887, 14391, 14363 (all UT). Kauffman, Marquette, Michigan, Aug. 27, 1906, on ground in birch woods, as *L. rugosoreticulata* (UM), and same locality, beech woods, Kauffman, 533 (UM). Pennington, Whitmore Lake, Michigan, Sept. 14, 1907 (UM). Kauffman and Brown, Takilma, Oregon, Nov. 27, 1925 (UM). Stuntz, F-496, Washington (UM, Z), and F-211, Washington (UW).

*Observations.* — This is a conspicuous form when the wrinkles of the pileus are well developed, but all degrees of variation are common. The fruiting bodies photographed were all from one group. Many of the other species in this genus also show this character to a greater or a less degree.

(c) Var. *typicum f. olivaceum* Singer, f. nov.

A typo pileo colore primum olivaceo differt.

Similar to *f. typicum* in all respects except that the pileus and sheath of the stipe are olive in color at first, and gradually fade to yellowish.

*Habitat.* — Same as that of *f. typicum*.

*Distribution.* — Siberia.

*Material studied.* — Collections by Singer (L).

*Observations.* — This form has all the characters of the type form except color, even to becoming yellowish, as in *f. typicum*, when old, and then is indistinguishable from it. Both forms have been collected growing near each other, but *f. olivaceum* always occurred in large homogeneous groups and appears to be a minor mutation from *f. typicum*.

(d) Var. *typicum f. album* (Maire apud Rea), comb. nov.

*Lepiota amianthina* var. *alba* Maire apud Rea, Brit. Bas., p. 76. 1922.

"Differs from the type in being entirely white."

*Habitat.* — Same as that of *f. typicum*.

*Distribution.* — England and United States.

*Material studied.* — Parlin, 15485 (FH, UM), Canton Point, Maine, Nov. 16, 1942.

*Observations.* — The dried specimens of the one collection placed here varied from nearly white to pale yellow. We have not seen fresh material and have recognized the form largely on the strength of Maire's identification. In keeping with our treatment of color variants, it is here treated as a form. The reaction of the cuticle in KOH should readily distinguish this form from *f. album* of *C. carcharias*.

(e) Var. *sublongisporum* Singer, var. nov.

Illustration: Figure 10, spores (p. 84).

A typo colore pilei (squamusis rufo-badiis interstitiisque dilute aurantio-flavis) et sporis aliquantulum majoribus et contextu tramali lamellarum KOH ope discolorato et pallido-cinnamomeo-tincto differt. Habitatio: ad humum et ligna putridissima inter muscos et folia delapsa in silvis mixtis et piceinis Americae Borealis.

Pileus 10–35 mm. broad, obtusely umbonate when young, becoming campanulate or expanded-umbonate, sometimes broadly convex, margin at first appendiculate with remnants of the veil, surface dry and covered with small granulose scales, the scales tending to remain distinct in old or dried carpophores, color at first evenly "mahogany red" to "auburn" (deep brownish red) from the highly

colored scales, ground color "light orange yellow" and more conspicuous on disc, causing the surface to appear paler toward the margin, in age or when dried more or less "amber brown" (bright yellowish brown); flesh thin, tinged rufous or in age pallid, odor none, taste not distinctive; lamellae bluntly adnate becoming sinuate-adnate at maturity, close to crowded, moderately broad, pale yellowish ("warm buff" to "pale orange yellow"), edges even; stipe 30-60 mm. long, 3-6 mm. thick at apex, tapered upward to nearly equal, lower portion sheathed by granular-tomentose veil remnants that are concolorous with the scales of the pileus, sheath terminating a more or less evanescent fibrillose median zone, white pruinose above but soon yellowish and when dried pale tawny, the sheath drying slightly darker.

Spores  $(5.3)6.2-7.5(8) \times 2.8-3.8 \mu$ , smooth, narrowly ellipsoid, amyloid; basidia four-spored,  $22-24 \times 5.5-7 \mu$ , hyaline in KOH, yellow in iodine, narrowly clavate; pleurocystidia and cheilocystidia not differentiated or very rare, when present basidium-like but with one obtuse sterigma-like apical prolongation; gill trama homogeneous, subparallel, hyaline in KOH near the gill edge but in many sections tinged cinnamon toward the junction with the trama of the pileus, yellow in iodine; pileus trama moderately dark to pale ferruginous cinnamon near the cuticle and paler toward the subhymenium when revived in KOH, the hyphae compactly interwoven, clamp connections present; cuticle of pileus and subcuticular hyphae deep ferruginous when revived in KOH (almost blackish when KOH is applied directly to cap surface), the cells globose to ellipsoid and in chains, the latter readily breaking up into single cells, a fairly large number of subcylindric to clavate-pedicellate cells often present in addition, the globose and ellipsoid cells  $14-32(40) \mu$  in the longest dimension, the pedicellate cells at times up to  $60 \mu$  long.

*Habitat.* — Solitary to gregarious on rich humus, very rotten logs, among mosses and fallen leaves in mixed forests or on needle carpets under spruce. It usually fruits during the late summer and fall, but Hesler has one collection from under red spruce made in June at an altitude of 5,200 feet.

*Distribution.* — It is known across the North American continent from New York, Ontario, and Washington. It has also been found in Tennessee in the Great Smoky Mountains National Park. Collections from Maine and Oregon, which appear to belong here but

which are not typical in coloration, have also been examined. The variety probably occurs throughout the range of var. *typicum* in North America, but is not so common.

*Material studied.* — Fresh carpophores from the Huntington Wild Life Forest, Newcomb, New York, Sept., 1941, Singer, 97 (FH), have been studied and are designated as the type. Other collections are as follows: Smith, 16881, Ermine Creek Trail, Baker National Forest, Washington (UM). Roy F. Cain, Bear Island, Lake Timagami, Ontario, Sept., 1936 (UM). The following collections of dried material have also been examined: Hesler, 10433 (UM, UT), 10915, 13928, 13988 (all UT). Hesler and Smith, 9764 (UM). Kauffman, Lake Quinault, Washington, Oct. 31, 1925 (UM); Kauffman, same locality, Nov. 5, 1925 (UM). Parlin, Canton Point, Maine, 15476 (UM), with carpophores paler than usual. Other atypical collections are as follows: Smith, 4656, Sand Point, Lake Timagami, Ontario (UM). Zeller, 9179, Oregon (UM, Z).

*Observations.* — The colors of both fresh and dried carpophores are quite distinctive and nearly always serve as an accurate characteristic between var. *sublongisporum* and var. *typicum*. Somewhat bleached or faded fruiting bodies are sometimes found as indicated in the material cited, but when these are sectioned and mounted in KOH the pallid-cinnamon gill trama and darker pileus trama were found to be constant. No white forms with these characters have been met with. In dried specimens the gills of var. *sublongisporum* are consistently darker orange buff than in var. *typicum*. The spore size is somewhat variable. In Smith, 16881, the spores were not more than  $6.3 \mu$  long. In most collections this is near the lower limit of the range. The granulose scales on the pileus are typically coarser and more persistent than in var. *typicum*. In the character of the veil as well as in color var. *sublongisporum* approaches *C. fallax* but can be distinguished at once by the sharp difference in both the size and the shape of the spores. In addition, the annulus is never so well formed and persistent.

(f) Var. *longisporum* (Kühner), comb. nov.

*Lepiota amianthina* var. *longispora* Kühner, Bull. Soc. Mycol. Fr., 52: 204. 1936.

? *Agaricus Jasonis* Cooke and Massee, Grevillea, 16: 77. 1887.

? *Armillaria Jasonis* Saccardo, Syll. Fung., 9: 12. 1891.

Illustration: (?) Cooke, Illus. Brit. Fungi, 1113, pl. 955.

Pileus 2.5 cm. broad, campanulate, hemispheric or convex, rhubarb yellow, granulose, then tessellate-roughened from distinct pyramidal floccules which are concolorous, or which break off leaving a brownish-red patch on a background of golden ocher; flesh with a distinct horn-colored line, the odor weak and not earthy; 32 lamellae reach the stipe, 3-5 tiers of lamellulae, yellowish white, becoming subhorizontal, adnate or slightly sinuate; stipe 2.5 cm. long, 3 mm. thick, equal, with an ocher-brown floccose-woolly covering, the apex naked or with soft fibrils and yellowish gray brown, stuffed with a pith, flesh brownish in the base, yellowish above, finally entirely brown; cortina arachnoid-woolly but not forming a membranous annulus as in *C. (Lepiota) carcharias*.

Spores distinctly elongated,  $7-9 \times 4-4.7 \mu$ , ellipsoid, or often somewhat ventricose-fusoid, faintly amyloid; basidia four-spored,  $21-22 \times 6.5-7 \mu$ ; hyphae with clamp connections.

*Habitat.* --- On decaying stumps in woods of *Picea*. August.

*Distribution.* --- France (Alps) and also England, if the synonymy is accepted.

*Material studied.* --- None. The account is taken from Kühner's original description.

*Observations.* --- As we have indicated above, we suspect that *Agaricus Jasonis* Cooke and Massee is the same as Kühner's variety. The flesh of *Ag. Jasonis* is described as reddish, but as illustrated by Cooke it is merely ochraceous buff and, consequently, it does not appear advisable to place much emphasis on this difference until it can be checked from fresh material. A difference in size of the carpophores should not be assumed simply on the basis of the two descriptions, since it is evident that not much is known of the variation of this fungus. Neither can the strong odor as described for *Ag. Jasonis* be given much emphasis taxonomically. Kühner reported the odor as weak, but obviously one was present in his specimens. In *f. rugosoreticulatum* the odor varies greatly, and its presence is not correlated with the wrinkles of the pileus. The iodine reaction of the spores of *Ag. Jasonis* must be ascertained before the species can be assigned to any other position in our classification. Although we do not record this variety as occurring in North America, we have seen one fruiting body, collected by L. K. Henry of Pittsburgh, Pennsylvania, which would key out here by virtue of its large spores. Since no information on the macroscopic characters of the fresh

fruiting body is available and since there are some slight discrepancies in the microscopic characters, we have been unable to arrive at a definite conclusion in regard to its proper place in our classification.

#### KEY TO VARIETIES AND FORMS OF *C. AMIANTHINUM*

- I. Spores 4.5–6.5 (7.5)  $\mu$  long. Gill trama hyaline in KOH . . . . . var. *typicum*
  - A. Pileus conspicuously rugose-reticulate . . . . . f. *rugosoreticulatum*
  - B. Pileus not as above; often slightly wrinkled
    1. Pileus yellow to tawny at first . . . . . f. *typicum*
    2. Pileus olive when young . . . . . f. *olivaceum*
    3. Pileus white or whitish . . . . . f. *album*
- II. Spores regularly 6.2–8 or more  $\mu$  long. If spore size intergrades, then gill trama pale cinnamon in KOH, at least on some of the sections
  - A. Spores regularly 2.8–3.8  $\mu$  broad; gill trama pale cinnamon in KOH  
var. *sublongisporum*
  - B. Spores 4–4.7  $\mu$  broad and 7–9  $\mu$  long . . . . . var. *longisporum*

#### 11. *Cystoderma fallax*, sp. nov.

Illustrations: Plate IV; Text Figure 8, spores (p. 84).

Pileo 2–5 cm. lato, interdum abrupte umbonato, margine primum vel fragmentis membranaceis ornato, superficie initio squarruloso-granulosa, demum pulveracea, vel squamis circa discum persistentibus, fulvo-ferrugineis instructa; carne albida vel superficiei subconcolori; lamellis adnatis vel rotundato-adnexis, confertis, intermixtis, angustis, carneo-alutaceis, integris; stipite 30–60 (80)  $\times$  3–7 mm., plerumque incrassato basin versus vel deorsum clavato, subinde subaequali, solido, intus pallido vel flavidulo, cothurnato ad annulum distantem, membranaceum tegumenti granulosi causa quod a carne strato membranaceo divisum est, ex quo squamulae densae granulosa oriuntur, glabro subsericeove ac pallide alutaceo supra annulum; annuli persistentis superficiei supera sericea vel pallide alutacea; sporis albis in cumulo, 3.5–5 (5.5)  $\times$  2.8–3.6 (4)  $\mu$ , levibus, amyloideis; basidiis 18–22  $\times$  4–5  $\mu$ , tetrasporis; cystidiis nullis; textura tramali lamellarum ex hyphis subparallelis vel in parte media subintertextis consistente; cuticula e catenulis hypharum globosarum vel ellipsoidearum et hyphis cylindricis sparsis consistente, obscure cinnamomeae KOH ope. Habitatio: ad humum, muscos, acus et ligna coniferarum putridissima in silvis acerosis vel mixtis, vere et autumno in parte occidentali Americae Borealis.

Pileus 2–5 cm. broad, obtuse to somewhat convex when young, the margin incurved, expanding to campanulate or expanded-

umbonate, the umbo sometimes abrupt and conspicuous, the margin at first decorated with membranous flaps of the veil remnants, surface dry and at first covered with erect granulose scales, finally becoming more or less evenly granulose or powdery or the scales persistent around the disc, color evenly "Sanford's brown" to "amber brown" when fresh, between "russet" and "ochraceous tawny" when dried (almost ferruginous when fresh, duller rusty brown when dried); flesh thick in the disc, thin toward the margin, whitish to tinged with the color of the pileus, odor and taste not distinctive or at times subnauseous; lamellae adnate to rounded-adnexed, close, 2-3 tiers of lamellulae, narrow to moderately broad, whitish or tinged buff, when dried "pinkish buff," edges even; stipe 3-6 (8) cm. long, 3-7 mm. thick at apex, usually enlarged downward or base narrowly clavate, sometimes equal or nearly so, fleshy and solid, pallid to yellowish within, sheathed up to the flaring membranous annulus with a granulose covering similar in texture and color to the granules of the pileus, the sheath composed of an inner membranous layer on which are the closely arranged granular scales, scales smaller and more poorly formed downward, glabrous and somewhat silky above the annulus and pallid to pale buff, dull tawny above the annulus in dried carpophores, base often conspicuously white-mycelioid; annulus persistent, upper surface silky and pallid to pale buff.

Spores white in mass,  $3.5-5 (5.5) \times 2.8-3.6 (4) \mu$ , broadly ellipsoid to nearly drop-shaped, smooth, amyloid; basidia four-spored,  $18-22 \times 4-5 \mu$ , hyaline in KOH, yellowish in iodine; pleurocystidia and cheilocystidia not differentiated; gill trama of parallel hyphae or the central portion becoming somewhat interwoven, yellowish in iodine; pileus trama floccose, interwoven, pale tawny brownish under the cuticle, paler to hyaline toward the subhymenium, interwoven, yellowish in iodine, the hyphae with clamp connections; cuticle of pileus composed of chains of globose to ellipsoid cells  $10-40 \mu$  in diameter or  $20-40 \times 10-25 \mu$ , some pear-shaped and a few cylindric to subcylindric, the cells very dark rusty cinnamon in KOH (cap surface becomes almost blackish if KOH is applied directly to it).

*Habitat.* — Scattered, gregarious, or subcespitose on humus, moss beds, needle carpets, or very rotten conifer logs in conifer forests of Douglas fir, pine, or balsam fir or in mixed forests of conifers and hardwoods (alder and cottonwood). Along our west coast it occurs at



elevations from sea level up to 5,000 feet. It fruits most abundantly from September to November along the coast of Washington and Oregon, but it has also been collected in late March in southern Oregon.

*Distribution.* — Western United States. It is known from California, Oregon, Washington, Idaho, and Colorado.

*Material studied.* — The following collections of fresh material have been studied and deposited in the University of Michigan Herbarium: Smith, 4305, 8076, 8084, 8254, 8746, 8908, 17056, 17100, 17272. The last is designated the type, and part has been deposited at the Farlow Herbarium. The following collections of dried specimens have been examined: J. M. Grant, Marysville, Washington, Oct., 1931, distributed as *Armillaria focalis* (FH). Zeller, 9180, Oregon (UM, Z). Rogers, Corvallis, Oregon, Nov., 1937 (UM, Z). Gruber, 18-5, March 28, 1942, Takilma, Oregon (UM). Epling, 96, Oregon (UM); 1221, Idaho (UM). Kauffman, Tolland, Colorado, Sept. 11, 1920, as *L. amianthina* (UM). Stuntz, 190, 403, Washington (UW).

*Observations.* — Kauffman's collection from Colorado is paler in the dried condition than the other collections cited above and appears to be an intermediate form connecting this species with *C. amianthinum*. In the character of its veil *C. fallax* is very similar to *C. granosum*, and the spores of both species are also somewhat alike in both size and shape. The two differ distinctly in color and habitat and to some extent in stature, but the last character is quite variable. So far as is known, the range of each also serves to distinguish them. In many respects *C. fallax* also resembles *C. carcharias*, but the reaction of the cuticle in KOH as well as the color of the pileus sharply separates it.

## 12. *Cystoderma granosum* (Morg.), comb. nov.

*Agaricus granosus* Morgan, Journ. Cincinnati Soc. Nat. Hist., 6: 63. 1883.

*Lepiota granosa* Saccardo, Syll. Fung., 5: 48. 1887.

*Armillaria granosa* Kauffman, Pap. Mich. Acad. Sci., Arts, and Letters, 2 (1922): 60. 1923.

### Illustrations:

Plate V; Text Figure 12, spores (p. 84).

Hard, The Mushroom, Edible and Otherwise. Its Habitat and Its Time of Growth, pl. vii, fig. 36.

Kauffman, Agar. Mich., Vol. II, pl. cxxix.

Marshall, The Mushroom Book, pl. 12, opposite p. 63.

Morgan, Journ. Cincinnati Soc. Nat. Hist., Vol. VI, pl. 3, upper figs.

Pileus 40–90 mm. broad, ovoid to convex when young, expanding to obtusely umbonate, broadly convex or nearly plane, margin somewhat incurved at first, surface dry and either more or less covered with small granulose scales or merely pulverulent or furfuraceous, sometimes more or less rugose-wrinkled, "ochraceous orange" (bright orange) on the disc, paler and more ochraceous yellow toward the margin or evenly colored over all; flesh thick, whitish or tinged ochraceous, odor not distinctive, taste not recorded; lamellae bluntly adnate to slightly adnexed, narrow (5–6 mm.), crowded, white to pallid tan, edges even; stipe 5–10 cm. long, 8–15 mm. thick, equal or tapering upward from a clavate base, straight or curved, fibrous-stuffed but becoming hollow, peronate by a granulose-furfuraceous sheath terminating in a median to superior rather large flaring or reflexed membranous and persistent annulus, sometimes the sheath broken into several annular zones, and usually more or less concolorous with the pileus over the outer surface, the inner or upper surface of the annulus silky and pallid orange buff, surface of stipe above annulus more or less pruinose and pallid to brownish.

Spores white in mass,  $4-5 \times 3 \mu$ , ellipsoid, amyloid, smooth; basidia four-spored,  $18-22 \times 3.5-5 \mu$ , yellowish orange in iodine, hyaline in KOH; pleurocystidia not differentiated; cheilocystidia basidium-like or occasionally up to  $6-8 \mu$  broad, thin-walled, clavate, hyaline, smooth; gill trama homogeneous or nearly so and of more or less parallel hyphae, hyaline in KOH; pileus trama with a cuticle of chains of inflated globose to ellipsoid cells  $10-40 \times 10-30 \mu$ , their walls dark to pale reddish brown in KOH and slightly but irregularly thickened, few cylindric hyphae present in the cuticle, tramal body of filamentous hyphae bearing clamp connections and hyaline in KOH near the subhymenium, pale tan under the cuticle, lactifers present and reddish tawny in iodine, the remainder of the hyphae yellow in iodine.

*Habitat.* — Gregarious to cespitose on rotten wood of deciduous trees such as maple, birch, and beech. Fruiting occurs during the late summer and fall. On the basis of our records it is most likely to be found around the middle of September. In some regions, such as the Adirondack Mountains of New York and the hardwood forests of northern Michigan, it often grows in considerable abundance, but, in general, seems to be one of the less common species.

*Distribution.* — It is known only from central and eastern North America. It has been found in Ontario in Canada and in Michigan, Ohio, New York, and Tennessee in the United States.

*Material studied.* — The following collections were studied in the fresh condition: Smith, Rock River, Michigan, Sept. 22, 1929 (FH, UM). Mains, 32-765, Harbor Springs, Michigan, Sept. 14, 1933 (UM). Smith, 33-969, Porcupine Mts., Michigan, Sept. 14, 1933 (UM); 847, Pack Forest, Warrensburg, New York, Sept. 12, 1934 (UM), and 1017, 1069, same locality, Sept. 16, 20, 1934 (UM). The following collections of dried material have been examined: Kauffman, Ithaca, New York, Sept. 6, 1903 (UM); Pellston, Michigan, Sept. 9, 1905 (UM); Bay View, Michigan, Sept. 7, 1905 (UM). Kauffman and Mains, North Elba, New York, Sept. 14, 1914 (UM). Kauffman, Elkmont, Tennessee, Sept. 19, 1916 (UM); North Elba, New York, Sept. 14, 1919 (UM). Kelly, 1844, Magnetawan, Ontario, Canada, late August, 1922 (UM); 871, Magnetawan, Ontario, Sept. 7, 1920 (UM); and 146, Parry Sound District, Ontario, Sept., 1919 (UM). Walters, Cleveland, Ohio, Oct. 19, 1941 (UM).

*Observations.* — No attempt has been made to distinguish a rugulose form from the typical form in this species because the character usually appears on at least some of the carpophores of any collection, and old pilei lacking it appear to be rare. This species is most closely related to *C. fallax*, which, apparently, has been identified as *L. granosa* by some Pacific Coast mycologists. For a comparison of the two see *C. fallax* (p. 116). In *C. granosum* the presence of cheilocystidia and lactifers in the flesh of the pileus are additional aids in identification if one is limited to herbarium specimens. The photograph published by Marshall (*loc. cit.*) is excellent for the young stages.

### 13. *Cystoderma subvinaceum* A. H. Smith, sp. nov.

Pileo (8) 10-25 mm. lato, subconvexo, granuloso-furfuraceo vel verrucoso-squamuloso, ad marginem subappendiculato, obscure opaco-vinaceo-fusco, demum gradatim pallidiore; carne alba pallidave, haud discolorante; lamellis confertis vel subdistantibus, angustis vel moderate latis, adnatis vel subdecurrentibus, latissimis in interiore parte tertia, pallidis vel alutaceis, aciebus integris; stipite 30-50 × 3-5 mm., latiore ad basin, solido, intus pallido, annulo fugaci, lacero, sericeo, supra annulum pallide vinaceo, infra annulum vesti-

mento subfibrilloso-granuloso pileo concolori oblecto, vestimento dein rupto et zonas annuliformes squamasque subrecurvatas formante, supra annulum pallide sordideque vinaceo et subpruinoso; sporis hyalinis, amyloideis,  $3.5-4.2 \times 2-2.3 \mu$ , oblonge ellipsoideis; cystidiis nullis vel haud distinctis, basidiiformibus; cellulis cuticulae inflatis, globosis, subglobosis, ellipsoideis, subcylindraceis, pallide olivaceo-griseis KOH ope. Habitatio: singulatim ad ligna putrida in Canada in America Boreali.

Pileus (8) 10-25 mm. broad, obtuse to convex, soon broadly convex to nearly plane or at times the disc slightly depressed, surface dry and granulose-furfuraceous or covered with small wartlike scales, margin at first slightly appendiculate, soon denuded and merely granulose to subtomentose, color very dark dull vinaceous brown (near "Hay's brown") at first, gradually becoming paler in age, pale vinaceous with slightly darker vinaceous brown ("fawn-color") disc, the remainder "vinaceous buff," scales or warts usually slightly darker than the ground color; flesh white to pallid and remaining pallid in dried specimens, no color changes noted, odor not distinctive, taste not recorded; lamellae close to subdistant, 42-48 reach the stipe, 2-3 tiers of lamellulae, narrow to moderately broad, bluntly adnate to subdecurrent and broadest near the stipe, pallid or tinged buff, not discoloring on drying or "pinkish buff" when dried, edges even; stipe 3-5 cm. long, 3-5 mm. thick at apex, slightly enlarged downward to a clavate base, solid, pallid within (whitish), surface sheathed up to the superior evanescent ragged annulus with a subfibrillose-granulose sheath similar in color to the scales of the pileus, the sheath soon torn up into subannular zones or somewhat recurved scales, pallid dull vinaceous and subpruinose above the annulus; annulus silky and pallid vinaceous above when well formed, concolorous with the pileus on the margin or under side, soon evanescent.

Spores hyaline in KOH, amyloid,  $3.5-4.2 \times 2-2.3 \mu$ , narrowly ellipsoid; basidia  $16-18 \times 3.5-4 \mu$ , four-spored; pleurocystidia not seen, cheilocystidia hardly differentiated, basidium-like and  $3-5 \mu$  in diameter at the apex; gill trama of more or less parallel hyphae, the subhymenium of narrow much-branched hyphae, dull rusty brown in all parts (hymenium, subhymenium, and flesh) in iodine; pileus trama with a cuticle of inflated to elongated cells  $25-50 \times 10-20 \mu$  (some globose, some ellipsoid, some cylindric), pale

olivaceous gray when revived in KOH, dull rusty brown in iodine; clamp connections present.

*Habitat.* — Scattered on mossy rotten logs. September. Rare.

*Distribution.* — Lake Timagami region of Ontario, Canada.

*Material studied.* — Smith, 4755, coll. Roy F. Cain, Lake Timagami, Ontario, Sept. 10, 1936 (UM), type. Smith, 4560, same locality, Sept. 5, 1936.

*Observations.* — The outstanding features of this species are the habitat, the amyloid spores, and the color the cells of the cuticle assume when revived in KOH. The species appears to resemble *C. haematites* in some respects but differs in its unchanging gills and pallid flesh of the stipe as well as in its narrow spores. There should also be a distinct difference in the color of the carpophores, but we have not seen fresh specimens of the European species to verify it. The habitat of *C. subvinaceum* on decaying logs is an additional difference evident from the descriptions.

14. *Cystoderma haematites* (Berk. & Br.) Kühner et Maire,  
Bull. Soc. Mycol. Fr., 50:14. 1934.

*Agaricus haematites* Berkeley and Broome, Ann. and Mag. Nat. Hist., Ser. 5, 1:18. 1878.

*Armillaria haematites* Saccardo, Syll. Fung., 5:77. 1887.

*Lepiota haematites* Ricken, Die Blätterpilze, 1:328. 1913.

Illustrations:

Bresadola, Icon. Mycol., pl. 49, fig. 1.

Cooke, Illus. Brit. Fungi, no. 54, pl. 45.

Konrad et Maublanc, Icon. Sel. Fung., Vol. III, pl. 202, as *Collybia lilacea* Quélet f. *robusta*.

"P. 2-4 cm. red liver colour, hemispherical, then somewhat flattened, or depressed at the centre, thin, *slightly hispid*, becoming smooth. St. 4-6 cm.  $\times$  3-5 mm., *concolorous below the ring, whitish above*, equal; base *thickened*, white floccose. Ring *whitish, then concolorous*, submembranaceous, narrow, inferior, scaly beneath, torn, often fugacious. Gills *white then whitish tinged with rose*, and becoming rose colour when rubbed, sinuato-adnate, or shortly decurrent, scarcely crowded, narrow, 3 mm. broad. Flesh *pale liver colour, slightly yellowish in the st.* Spores white, ovoid-ellipsoid,  $4 \times 3 \mu$ ."

*Habitat.* — Gregarious to cespitose on moss and needle carpets under firs. Late fall. Rare.

*Distribution.* — England, France, and Italy.

*Material studied.* — None.

*Observations.* — The description is quoted from Rea (1922). Kühner and Maire (1934) state that the spores are amyloid. *C. subvinaceum* appears from the descriptions to resemble *C. haematites* in some respects. For a comparison of them see page 122. Konrad and Maublanc (*loc. cit.*) have illustrated an exannulate form of *C. haematites* under the name *Collybia lilacea* Quélet (f. *robusta*). The true *C. lilacea* Quélet is now considered a synonym of *Baeospora myriadophylla* (Pk.) Singer.

#### EXCLUDED AND DOUBTFUL SPECIES

*Agaricus (Lepiota) polyglonus* Berk. & Br., Journ. Linn. Soc., 11: 509.

1871. This is described as allied to *Ag. granulatus*. We have not seen specimens, and the information on it is meager.

*Cystoderma Bucknallii* (Berk. & Br.) Singer, *Schweizer. Zeitschr. Pilzk.*, 17: 53. 1939. Retained in *Lepiota*.

*Cystoderma echinata* (Fr.) Singer, *Schweizer. Zeitschr. Pilzk.*, 17: 53. 1939.

*Cystoderma Eyrei* (Masse) Singer, *Schweizer. Zeitschr. Pilzk.*, 17: 53. 1939.

*Cystoderma fumoso-purpurea* (Lasch) Fayod, *Ann. Sci. Nat., Sér. 7*, 9: 351. 1889.

*Cystoderma Hetieri* (Boud.) Singer, *Schweizer. Zeitschr. Pilzk.*, 17: 53. 1939.

*Cystoderma ochracea* (Bull.) Fayod, *Ann. Sci. Nat., Sér. 7*, 9: 410. 1889. If recognized as validly published it would become a synonym of *C. amianthinum*.

*Cystoderma seminudum* (Lasch) Fayod, *Ann. Sci. Nat., Sér. 7*, 9: 351. 1889.

*Lepiota amianthina* var. *Broadwoodiae* (Berk. & Br.) Saccardo, *Syll. Fung.*, 5: 48. 1887. If the description of the pileus is correct, it cannot be a variety of *C. amianthinum* and may not be a *Cystoderma*.

*Lepiota asprata* (Berk.) Saccardo, *Syll. Fung.*, 5: 48. 1887.

*Lepiota carcharias* var. *incarnata* Saccardo, *Fung. Ital. Crypt.*, 1: 83. 1915. Apparently this is a *nomen nudum*. It was taken from a manuscript of Bresadola's.

*Lepiota Terreji* (Berk. & Br.) Saccardo, *Syll. Fung.*, 5: 47. 1887.

This was originally described as *Ag. Terrei* Berk. & Br., *Ann. Mag. Nat. Hist.*, Ser. 4, 6:462. 1870, and is found in Rea as *Lepiota cinnabarina* var. *Terreyi*. From the illustration by Saunders and Smith, *Mycol. Illus.*, pl. 35, figs. 1-5, we might think it only a color form of *cinnabarinum*, but we have no data on cystidia or iodine and KOH reactions. Consequently, it cannot be placed in our classification.

*Lepiota granulosa* var. *rufescens* (Berk. & Br.) Saccardo, *Syll. Fung.*, 5:47. 1887. Apparently this is a true *Lepiota*.

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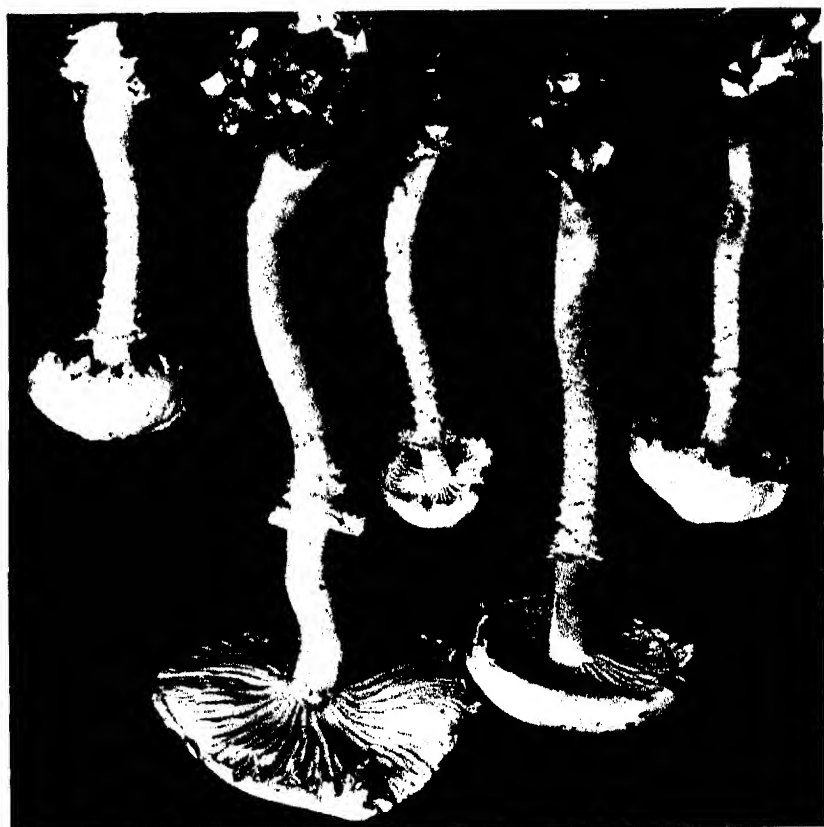
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*Cystoderma granulosum* var. *typicum*, f. *typicum*.  $\times 1$







*Psilocybe cubensis* (Fr.) Smith & Singer. × 1





*Cystoderma amianthinum* f. *rugosoreticulatum* (Lorinser) Smith & Singer.  $\times 1$





*Cystoderma fallax* Smith & Singer.  $\times 10$





*Cystoderma granosum* (Morg.) Smith & Singer, x 1

(Photograph by courtesy of Maurice B. Walters)





# THE GENUS LIMACELLA IN NORTH AMERICA

HELEN V. SMITH

## INTRODUCTION

**T**HE present study represents the first part of an investigation of the North American species of *Lepiota*. My interest in the genus was first aroused during the fall of 1937, when I accompanied my husband, Dr. Alexander H. Smith, on a collecting expedition to northern California. On subsequent collecting trips I began a critical study of the genus with the hope that I might become familiar with our North American species. Since these fungi are generally sporadic in their appearance, field work must be spread over a rather long period of years to be of much value in establishing the distribution of any species and its relative abundance in the *Lepiota* flora. Fortunately, circumstances have favored this approach to the study of the genus. In addition to field work carried on from 1937 through 1941 my investigation has been greatly facilitated by access to the *Lepiota* collections in the University of Michigan Herbarium and by authentic material borrowed from other institutions.

One of the first features about *Lepiota* to impress me was the presence in the genus of certain very distinct groups of species. Another was the great diversity of the microscopic characters, such as the shape of spores and the type of cuticle on the pileus. One group was found to differ sharply from the majority of the species in having divergent gill trama. This character was also correlated with subviscid to glutinous pilei. These species were chosen for particular study because it seemed very apparent that they were by no means "typical" of *Lepiota*. A survey of the literature indicated that from the time of Fries mycologists had been puzzled by the relationships of the group and that several attempts to arrange them in a more natural classification had already been made. Since the number of species with divergent gill trama is relatively small and since, with two exceptions, they are all somewhat rare, herbarium material had to be relied upon to a larger extent than will

be necessary in future studies in *Lepiota*. From the material and information available, however, it was evident that the group does represent a distinct and natural genus and that its relationships are with *Amanita* rather than with *Lepiota*.

#### HISTORY

Two of the species, *Lepiota illinita* and *L. delicata*, now included in *Limacella* were originally placed by Fries (1821) in the tribe *Lepiota* of *Agaricus*. He later (1874) included those with *Agaricus medullatus*, *A. gliodermus*, *A. pinguis*, and *A. inoculatus* in his section *Viscosae* of *Lepiota*. He also placed in the tribe *Amanita* *A. lenticularis* (*guttatus*), *A. Persooni*, and *A. aridus*, the first of which is now definitely known to belong in *Limacella*, thus making it evident that he was aware of their close relationship to the typical *Amanitae*. Quélet (1888) united with the species mentioned above all other known viscid species of *Lepiota*. Earle (1909) was the first who validly published the genus *Limacella*. *Myxoderma* Fayod (1889) and *Amanitella* Maire (1913) are untenable. Maire, however, was the first to define *Limacella* precisely in such a way that it included a group of obviously closely related species. He pointed out that the presence of divergent gill trama was the important character and that because of it the genus was more closely related to *Amanita* than to *Lepiota* in the restricted sense. Earle merely characterized the genus as: "Putrescent, solitary or gregarious: pileus fleshy, viscid, discrete from the stipe: lamellae free: spores white: veil forming an annulus: stipe central, slender, fleshy, no cortex." He selected *L. delicata* as the type. Two of the characters he mentioned deserve some comment. The pileus is supposed to be discrete from the stipe, a character of both *Amanita* and *Lepiota* but, apparently, this is not too distinct in *L. glioderma*. The lamellae are supposed to be free, but, again, in *L. glioderma* and other species now placed in the genus they are slightly attached. These reasons led Quélet to place *L. glioderma* in *Armillaria*.

Maire (1913) published the results of a careful histological study on four viscid species of *Lepiota*: *L. lenticularis*, *L. illinita*, *L. glioderma*, and *L. irrorata*. He found that the first three had an amanitoid gill structure, i.e. bilateral trama, whereas the fourth had the typical regular trama and cheilocystidia usually found in the true *Lepiotae*. As a result of this study, while unaware of Earle's prior

name he proposed the name "*Amanitella*" to include the species characterized thus: carpophores without a volva, annulate, cuticle of pileus separable, viscid; trama of gills bilateral, lamellae rounded toward the stipe. These species differ from *Amanita* principally by the lack of a volva and by the presence of rounded lamellae, and from *Lepiota* in having bilateral trama. He selected *L. lenticularis* as the type and included *L. illinita* and *L. glioderma*. Maire (1914) later adopted the name "*Limacella*" for his genus. From the information available at present there appears to be no good reason for excluding *L. glioderma*. The genus as originally defined by Earle obviously included any viscid *Lepiota*, and in this respect was as artificial as the arrangement it was designed to supersede. Furthermore, the two characters in question do not now appear to be as important as has been assumed by some investigators. The gills are slightly attached in some true *Amanitae* and, so far as is known (Kühner, 1936), there is not a really distinctive anatomical difference between species like *L. glioderma*, in which the stipe is not obviously readily separable from the flesh of the pileus, and the species of *Amanita* which possess this character. Consequently I have followed Maire's disposition of the species named above. Murrill (1914) recognized the genus *Limacella* in the sense of Earle and included nine species. Kauffman (1924) did not recognize the genus but, instead, placed all viscid species in the sections *Lubricae* and *Viscidae*, regardless of the nature of the gill trama. Kühner (1936) recognized the genus in the sense of Maire, and this is also the concept as recognized by Singer (1939) in his studies of the genera of the *Agaricales*. Since this concept is the one most accurately expressing the limits and natural relationships of the genus, it is accepted here.

#### DESCRIPTION OF LIMACELLA

Pileus fleshy, putrescent, variously shaped but usually convex to obtusely umbonate or nearly plane, surface subviscid to glutinous, glabrous, sometimes appearing fibrillose-streaked beneath the gluten, sometimes appressed or crustose-scaly, color variable, white, cream color, grayish, grayish olive, pinkish to deep reddish brown; flesh often thick in the disc, usually thin elsewhere, soft, often with a farinaceous or otherwise distinctive odor or taste; lamellae free or sinuate and attached by a line or deeply adnexed, moderately

broad and close, thin, usually white or at least paler than the pileus; stipe fleshy, central, more or less readily separable from the tissue of the pileus, often sheathed with the remains of a glutinous to merely viscid universal veil, sometimes dry, annulus usually present, sometimes persistent and sometimes not forming, or merely present as a superior somewhat fibrillose zone from the thin fibrillose partial veil.

Spores white, small, usually globose to subglobose,  $3.5-4.5\ \mu$  in diameter but in some broadly ellipsoid and up to  $6-7\ \mu$  long, no germ pore present, nonamyloid, smooth or in some appearing finely stippled under an oil-immersion lens; basidia usually four-spored; neither pleurocystidia nor cheilocystidia differentiated but the gill edges often with sterile basidium-like cells; gill trama clearly bilateral, either with or without a central strand, subhymenium parenchymatous, lactifers present or absent; pileus trama loosely floccose, lactifers present in some, clamp connections present; cuticle of pileus differentiated into a more or less turflike covering, the apical cells of the component hyphae attenuated, narrowly clavate to cylindric or in some species narrow and greatly elongated, more or less gelatinous.

As defined here, all viscid Lepiotae with regular gill trama are excluded. From species of *Armillaria* with divergent gill trama the *Limacellae* are distinguished by the nonamyloid and very small spores, the free or nearly free gills, and the more slender stature. The *Armillariae* in question are mostly large hard-fleshed species with long-decurrent to broadly adnate gills. From *Amanita* *Limacella* is distinguished by its lack of a volva and its very small spores. *Cystoderma* is excluded because of its regular gill trama and dry granulose pilei, although some tendency toward the production of sphaerocysts was noted on the cuticle of *L. roseicremea*. *Amantiopsis*, if considered distinct from *Amanita*, differs in the presence of a volva and the lack of an annulus.

#### COMMENTS ON THE CHARACTERS OF THE SPECIES

In general, the plants of this genus are quite similar in appearance, but the colors are not especially attractive, although they do furnish one of the chief characters by which species are recognized. A rather wide range of variation, however, must be allowed. The character of the surface of the stipe, whether viscid to glutinous or dry, is the major difference and the one by which the genus is divided into

two sections. The color of the gluten — hyaline, yellow, or red — has been given emphasis, and considerable importance has been attached to the color changes that take place in the gluten of the stipe in the *L. illinita* series. Although the characters of the annulus, particularly whether it is persistent or evanescent, have been somewhat emphasized, these still need to be confirmed by a study of more fresh material in the *Lubricae*. In the *Viscidae*, those with dry stipes, the annulus received some prominence in the classification. Two series of species are represented, one containing *L. lenticularis*, in which the annulus is large, flaring, and persistent, and the other, represented by *L. glioderma*, with evanescent or poorly formed annuli.

Aside from the viscosity or glutinous nature of the surface of the pileus, the macroscopic characters of the cuticle are of secondary importance. The color, when not located in the cuticle, is in the hyphae just beneath it. The pilei are usually glabrous, but in weathered specimens some checking may occur to produce crustose scales or radial cracks. The characters of the lamellae are mostly of secondary importance. In *L. oblita*, however, the gills are said to be forked, and this may prove to be of some significance. Considerable emphasis has been placed on taste and odor since, from the information available, they appear to be quite constant. It may eventually be found desirable to use them as characters for the recognition of varieties rather than species.

Although established on the character of the gill trama, *Limacella* possesses few microscopic characters of major importance in the classification of its species. The spores are all small and mostly globose to subglobose. In some species they appear to be finely stippled, but the character is so difficult to observe that it is questionable whether it can ever be used to advantage. Pleurocystidia and cheilocystidia are not differentiated. In the cuticle of the cap important microscopic differences are rather useful in the recognition of species. There are two main types of cuticle. In such species as *L. lenticularis* and *L. solidipes* the terminal cells are fairly broad and short and become narrowed toward the ends. These are borne at the ends of chains of short-cylindric cells and resemble filaments of *Rivularia*. A slight variation occurs in *L. roseicremea*, in which the cells beneath the terminal cells are sometimes slightly inflated and nearly globose. A second type is clearly seen in such species as

*L. glischra*. Here the terminal cuticular elements are narrow, usually not over  $4\ \mu$  in diameter, and remain of the same width throughout their length. They are longer than the terminal cells of the first type and usually stand erect and closely packed, forming a turflike covering  $50\text{--}200\ \mu$  in thickness. The long cells may become appressed, when they are hard to distinguish, and may also give a streaked appearance to the pileus.

#### GENERAL CONSIDERATIONS

As a result of this study twelve species and three varieties of *Limacella* have been recognized in the agaric flora of North America. One new species and one new variety have been described. Murrill, in his account (1914) of the genus, treated nine species, three of which are no longer included in *Limacella*. With the exception of *L. agricola*, *L. delicata*, and *L. oblita* material of all the species included in this paper has been examined. Eleven are known to occur in the United States; one other is recorded only from the type locality in Jamaica. Only two species, both of which are northern in their distribution, appear to be relatively common in our agaric flora. Both *L. glioderma* and *L. illinita* occur across the continent in southern Canada and the northern United States; their range extends southward to California in the West and the Great Smoky Mountains in Tennessee and North Carolina in the East. *L. glioderma*, or a form of it, also occurs in Florida. *L. roseicremea* is known only from the type locality in Washington. *L. solidipes*, described from New York, has also been found in Washington and California. *L. glischra* is known from Ohio, Tennessee, and North Carolina in the East and from California and Washington in the Western states. Three species are reported only from the South — *L. roseola* from Virginia, *L. floridana* from Florida, and *L. Kauffmanii* from Virginia and Tennessee. In all, about seventy-five collections have been studied in either the fresh or the dried condition. These records, however, cannot be regarded as establishing the true pattern of distribution of the majority of the species, but, rather, indicate the areas where collecting has been most intensive.

The color names in quotation marks are taken from R. Ridgway, *Color Standards and Color Nomenclature* (Washington, D.C., 1912). All collections studied, except borrowed type material, are deposited in the herbarium of the University of Michigan.

I wish to express my appreciation to Dr. E. B. Mains, director of the University of Michigan Herbarium, who has placed the collections of *Lepiota* in the herbarium at my disposal. My husband, also of the herbarium, has turned over to me his unidentified specimens of *Lepiota* and *Limacella* as well as his field notes on the genus. His suggestions and comments have also proved helpful in the preparation of the manuscript. Dr. W. A. Murrill, of Gainesville, Florida, was most generous in sending to me the type collections of three species which he recently described from Florida.

## KEY TO SECTIONS

- I. Stipe viscid or glutinous ..... Lubricae  
 II. Stipe dry ..... Viscidae

## KEY TO SPECIES

## LUBRICAE

- I. Terminal cells of cuticular hyphae usually 3-5  $\mu$  in diameter at the base; apices at times somewhat attenuated
- A. Pileus bright yellow brown or reddish brown
1. Gluten of stipe "burnt sienna" (bright reddish brown) 1. *L. glischra*  
 2. Gluten of stipe "ocher yellow" (yellow) ..... 2. *L. Kauffmanii*
- B. Pileus dull brown to isabelline
1. Gills not forked; spores globose ..... 3. *L. floridana*  
 2. Gills forked; spores ellipsoid ..... 4. *L. oblita*
- C. Pileus white or disc tinged yellowish to pallid alutaceous or grayish
5. *L. illinita*
1. Pileus white to cream color, only slightly yellowish in dried material ..... var. *typicum*  
 2. Pileus grayish brown to pale clay color on the disc, brownish when dried ..... var. *argillacea*  
 3. Pileus white to cream-colored, but gluten staining reddish; flesh with farinaceous taste ..... var. *rubescens*
- II. Terminal cells of the cuticular hyphae usually 5-10  $\mu$  in diameter at the base; apices commonly attenuated ..... 6. *L. roseicremea*

## VISCIDAE

- I. Pileus white, slimy, 2.5 cm. broad; known only from Jamaica 7. *L. agricola*
- II. Known from temperate regions
- A. Spores strongly pseudoamyloid; pileus rose pink ..... 8. *L. roseola*
- B. Spores not or only slightly pseudoamyloid; pileus not truly pink or pinkish (some are reddish brown)
1. Annulus membranous, flaring and persistent; pileus white to buff-colored
- a. Gills or some other part of carpophore often stained olivaceous gray, at least in age; odor not distinctive .... 9. *L. lenticularis*



- b. Gills not staining; odor strong when carpophores are drying,  
resembling that of coal tar or *Tricholoma sulfureum* var. *Fischeri*
- c. Pileus white at first, odor and taste strongly farinaceous 10. *L. solidipes*
2. Annulus usually evanescent or ragged
- a. Odor and taste strongly farinaceous ..... 11. *L. glioderma*
- b. Odor and taste not farinaceous ..... 12. *L. delicata*

1. *Limacella glischra* (Morgan) Murrill, North Am.  
Flora, 10: 41. 1914.

*Lepiota glischra* Morgan, Journ. Mycol., 12: 203. 1906.

Pileus 2-4 cm. broad, convex or with a slight umbo, covered with a slimy viscid layer of gluten which is near "burnt sienna" in color, pale beneath the gluten, margin appendiculate from glutinous patches of the universal veil, flesh white, thick and soft in texture; lamellae close, broad, approximate, rounded toward the stipe, white, edges even; stipe 6-8 cm. long, 9-12 mm. thick at apex, equal or tapering slightly at the base, solid, surface covered with a thick layer of gluten similar to that on pileus, flesh white, base white-cottony, annulus evanescent, not membranous.

Spores spherical to subglobose, 3-4.2  $\mu$  in diameter, very pale yellowish brown in iodine, appearing finely stippled under oil immersion as though the wall were punctate or very finely echinulate; basidia 18-27  $\times$  6-7  $\mu$ , four-spored; neither pleurocystidia nor cheilocystidia present; gill trama of divergent hyphae of approximately uniform width (4-8-10  $\mu$  in diameter), no distinct central strand, the cells usually very loosely arranged, the subhymenium composed of very small compact cells 2-3 layers in depth; pileus trama of loosely interwoven hyphae of variable diameter, from 6-19  $\mu$  wide, lactifers present, clamp connections present, cuticle of very closely interwoven hyphae (2) 4-5  $\mu$  wide, with free ends obtuse, very compact, at times upright and occasionally appressed, trama below cuticle of similar hyphae but more loosely arranged.

*Habit, habitat, and distribution.* — Single on rich soil under conifers or hardwoods; North Carolina, Tennessee, Ohio, California, and Washington.

*Observations.* — This fungus may be readily recognized by the thick coat of bright reddish gluten that covers the entire plant. The gluten may be so thick that it drips off the cap at the margin.

This is particularly true in wet weather, when much moisture has been absorbed.

The spores appear finely stippled when stained in iodine and studied under oil immersion, but the wall does not appear to be roughened. Since several other species exhibit this same stippling and since it is very difficult to observe even under an oil-immersion lens, this character is not at present considered diagnostically important.

## 2. *Limacella Kauffmanii*, sp. nov.

Pileus 2-7.5 cm. latus, glutinosus, rufus, ad marginem subflavidus; lamellae pallidae, confertae, subliberae; stipes 3-7 cm. longus, 3-5 mm. crassus, glutinosus; velum glutinosum, flavidum; sporae  $4-5 \times 3 \mu$ . Specimen typicum in Herb. Univ. Mich. conservatum; legit C. H. Kauffman, Chain Bridge, Virginia, 1919.

Pileus 2-7.5 cm. broad, broadly oval at first, becoming obtuse, finally expanded and with a broad, low umbo, bay brown with a broad "raw sienna" margin when young, margin fading to "antimony yellow," covered with a thick pale-yellow layer of gluten, surface beneath the gluten somewhat streaked with stripes of lighter and darker yellowish brown, gluten mild in taste, surface even, splitting radially on the margin on drying, flesh white or pallid, cottony, somewhat watery at first, becoming thin abruptly halfway to the margin, odor none, taste subfarinaceous and substringent or none; lamellae equal, close to crowded, not broad (3-5 mm.), appearing free but adnexed by a narrow strip, at first white, becoming sordid whitish, deeply emarginate-rounded toward the stipe, abruptly narrow toward the margin, edge entire, thin; stipe 3-7 cm. long, 5-9 (10) mm. thick, equal or tapering upward, 3-5 mm. at apex, glutinous from the "yellow ocher" universal veil, apex almost naked, the gills terminating in a minutely floccose small circular ridge running around the stipe, surface at length subfloccose from the drying gluten, a brownish glutinous narrow annulus at times marked by the collapsing of the inner and outer veil, stipe brunnescent from dried gluten, stem solid and pallid within.

Spores  $4-5 \times 3 \mu$ , broadly ellipsoid to subglobose, light yellow in chloral hydrate-iodine solution; basidia about  $30 \times 6 \mu$ ; no pleurocystidia, cheilocystidia basidium-like; pileus trama mostly spongy but with a compact brownish layer beneath the cuticle,

cuticle composed of a turf of more or less upright hyphae 3-4  $\mu$  in diameter and with the terminal cells 150-200  $\mu$  long; gill trama divergent.

*Habit, habitat, and distribution.* — Single, gregarious or subcespitose in woods of oak or maple; Virginia and Tennessee.

*Observations.* — Although apparently quite similar to *L. glischra*, this fungus may readily be distinguished from it in the field by the distinctly yellow copious gluten which covers the entire plant. When dried the two species resemble each other closely. Kauffman collected a specimen at Chain Bridge, Virginia, in 1919 and tentatively identified it as *Armillaria megalopoda*. A. H. Smith later found *L. Kauffmanii* in the Great Smoky Mountains National Park, so that it appears to be southern in distribution.

### 3. *Limacella floridana* (Murrill), comb. nov.

*Armillaria floridana* Murrill, Mycologia, 35: 422. 1943.

Pileus 4.5 cm. broad, convex to plane, becoming slightly depressed, not umbonate, somewhat viscid, uneven, uniformly umbrinous-isabelline or slightly darker on disc, margin undulate-even; flesh white, unchanging, odor faint, pleasant; lamellae deeply emarginate, just touching the stipe, broad, ventricose, close, entire, inserted, white, fragile; stipe about 5 cm. long, 7-9 mm. thick, subfusiform, white, annulus median, small, white, persistent, stipe smooth, dry and glabrous above, viscid and floccose-squamulose below the annulus.

Spores globose, 3.8-4.2  $\mu$  in diameter, not staining in chloral hydrate-iodine solution, appearing minutely stippled under oil immersion; basidia 16.8-25  $\times$  4.2-6.3  $\mu$ , four-spored; neither pleurocystidia nor cheilocystidia present; gill trama divergent, no distinct central strand (divergence difficult to demonstrate on revived sections); pileus trama with a cuticle of turflike appressed or upright hyphae with attenuated ends, below this the tissue loosely floccose, lactifers few and scattered, mostly 2.1-4.2  $\mu$  wide.

When dried the pileus is "antique brown," and the gills are "argus brown."

*Habit, habitat, and distribution.* — Single in humus under oak; Florida.

*Observations.* — The persistent annulus and umbrinous color

should distinguish this species from *L. oblita*. Neither species, however, is sufficiently well known, and the possibility of their being synonymous is by no means excluded. The microscopic data are taken from the type.

4. *Limacella oblita* (Peck) Murrill, North Am. Flora,  
10:42. 1914.

*Agaricus (Lepiota) oblitus* Peck, Bull. Buffalo Soc. Nat. Sci., 1:41. 1873.

*Lepiota oblita* Saccardo, Syll. Fung., 5:71. 1887.

Pileus 5–7.5 cm. broad, viscid, convex or expanded, subumbonate, alutaceous inclining to tawny, faintly darker on the umbo, surface smooth or obscurely spotted or scaly from the rupturing of the universal veil; lamellae crowded, whitish or yellowish, free, sometimes forked; stipe 5–7 cm. long, about 6 mm. thick, equal or tapering slightly upward, smooth at apex, annulus obsolete, floccose and viscid below, stuffed or hollow.

Spores ellipsoid, 5–6 × 3–4  $\mu$ , smooth, hyaline; other microscopic characters unknown.

*Habitat and distribution.* — In deciduous woods; New York.

*Observations.* — No material of this species has been examined, and it is impossible to determine whether or not this plant should be included in *Limacella* in the sense in which the name is used in this paper. None of the characters are out of line, however, with those of the species now in the genus. It seems to be characterized by the yellowish forked gills and the floccose stipe. *L. floridana* appears to be very close.

5. *Limacella illinita* (Fries) Earle, Bull. New York  
Bot. Gard., 5:447. 1909.

*Agaricus illinitus* Fries, Syst. Mycol., 1:23. 1821.

*Lepiota illinita* Quélet, Champ. Jura et Vosges, p. 338. 1873.

*Amanitella illinita* Maire, Ann. Mycol., 11:337. 1913.

*Amanita* (subg. *Limacella*) *illinita* Gilbert, Le genre *Amanita* Persoon, p. 166. 1918.

*Myzoderma illinita* (Fries) Kühner, Le Botaniste, 17:144. 1926.

*Illustrations:*

Fries, Icon. Hymen., pl. 16, no. 1.

Bresadola, Icon. Mycol., Vol. I, pl. 42 (as *Lepiota illinita*).

Pileus 2–7 cm. broad, ovoid to obtuse when young, becoming campanulate to plane or retaining a slight umbo, surface covered

with a clear hyaline gluten which often drips from the margin of the pileus in wet weather, appearing faintly fibrillose-streaked beneath the gluten, pure white or whitish, the disc at times tinged with yellowish; flesh thin and relatively soft, white, odor and taste not distinctive; lamellae free, close, white to creamy white, narrow or becoming moderately broad (up to 1 cm. or slightly more), edges even; stipe 5-9 cm. long, 3-8 mm. thick, tapering slightly upward, fibrous, white or whitish and lower portion covered with a thick coating of hyaline gluten which terminates in a slight annular fibrillose but soon evanescent zone, white and silky above the annular zone.

Spores globose to broadly ellipsoid,  $4.5-5.5 \times 5-6.3 \mu$ , with a distinct apiculus, pale yellowish in iodine; basidia four-spored,  $20-26 \times 3-4 \mu$ , hyaline in KOH; neither pleurocystidia nor cheilocystidia differentiated; gill trama divergent from a central strand, the divergent hyphae rather large and loosely arranged; pileus trama very loosely floccose, clamp connections present; pellicle of pileus of gelatinous hyphae  $3-4 \mu$  in diameter and about  $120 \mu$  long, forming a compact turf, hyaline.

*Habit, habitat, and distribution.* — Single, scattered, or gregarious, on soil under hardwoods or conifers, on forest debris on humus under bracken fern, on mossy soil in cedar swamps, and in fields or under beech on sand dunes. In North America it is known from Quebec in Canada and from New York, Michigan, California, Oregon, and Washington in the United States.

*Observations.* — Because of the copious gluten which covers the pileus and stipe, and the soft flesh, this species is difficult to collect and photograph. It is one of the two relatively common species of *Limacella* and occasionally occurs in considerable abundance under the luxuriant growth of bracken fern which soon overruns all clearings in the forests of our Pacific Coast region if the land is neglected. Dried specimens of var. *typica* are white or only very slightly yellowish, whereas in the following two varieties the colors are darker, at least in some parts.

*Limacella illinita* var. *rubescens*, var. nov.

Sapor amarifarinaceus; stipes deorsum demum rubidus vel vinaceus; velum glutinosum, saepe rubescens. Specimen typicum in Herb. Univ. Mich. conservatum; legit F. L. Drayton, Barnet, Quebec, Sept. 25, 1938.

Pileus 2.5-7 cm. broad, convex, campanulate or broadly umbonate, white, very viscid; flesh rather fragile, white, 2-7 mm. thick, odorless, taste of pellicle slightly bitter, flesh bitterish-farinaceous; lamellae narrowly adnexed, close to subdistant, white; stipe 6-10.5 cm. long, 6-8 mm. thick, equal, solid, glutinous, white above but pinkish vinaceous toward the base or gluten becoming maroon red, annulus glutinous.

The microscopic details are as given for var. *typica*.

*Habitat and distribution.* — On ground under spruce and balsam. It has been found in Quebec in Canada, and in New York in the United States.

*Observations.* — This variety is distinguished from var. *typica* by the changing gluten (to pinkish or red) on the stipe and by the taste. In dried material as well as in fresh specimens the reddish color is noticeable. The flesh beneath is white to whitish. The type was collected by F. L. Drayton, September 25, 1938, on ground under spruce and balsam at Barnet, Quebec. Kauffman found it in the Adirondack Mountains of New York.

*Limacella illinita* var. *argillacea* (Fries), comb. nov.

*Agaricus* (*Lepiota*) *illinita* var. *argillacea* Fries, Hymen. Eur., p. 39. 1874.

*Amanita* (subg. *Limacella*) *illinita* var. *ochracea* Gilbert, Le genre *Amanita* Persoon, p. 167. 1918.

Pileus fleshy,  $6.5 \pm$  broad, broadly and slightly umbonate, glutinous, pellicle with a pale brownish tinge, "Verona brown" on disc, shading to "cinnamon buff" or pallid at the margin; flesh white, thin, odor and taste not recorded; lamellae free, creamy white, about 1 cm. broad, edge very slightly undulate; stipe 7.5 cm. long, 8 mm. thick, tapering slightly upward, glutinous, cinnamon buff, annulus obsolete.

The microscopic characters are as given for var. *typica*.

*Habitat and distribution.* — Under conifers in California and Oregon.

*Observations.* — This variety is distinguished by the dull-brownish tinge on disc and stipe in both fresh and dried condition, but the colors are by no means so pronounced as in either *L. glischra* or *L. Kauffmanii*. The gluten is hyaline to grayish on the stipe and does not change to reddish, as it does in the previous variety.

6. *Limacella roseicremea* Murrill, Mycologia, 4: 212. 1912.

Pileus up to 6 cm. broad, convex to plane, expanding slowly, umbo low and broad, smooth, glabrous and viscid, not striate, cream color tinged with rose, margin inflexed, flesh white, odor farinaceous; lamellae free, rather close, arcuate, white; stipe 5-10 cm. long, 12 mm. thick, enlarged at the base, white, fleshy, solid, smooth, viscid; annulus persistent, superior, ample, membranous, remaining stretched from margin to stipe for some time.

Spores 3.5-4.8 (5.2)  $\times$  3.1-4.7  $\mu$ , subglobose to broadly ellipsoid, hyaline to yellowish in iodine and very minutely punctate under oil immersion; basidia hyaline in KOH, very narrowly clavate, 18-24  $\times$  4.5-6  $\mu$ , four-spored; pleurocystidia and cheilocystidia not differentiated; gill trama divergent; pileus trama with a cuticle as in *L. solidipes*, but some cystidium-like cells present and some almost globose and in chains but with the terminal cell attenuated, not distinctly gelatinous in KOH.

*Habitat and distribution.* — On ground in the woods; Washington.

*Observations.* — This plant evidently resembles *L. illinita* to some extent macroscopically but is readily distinguished microscopically. In *L. illinita* the cuticular elements are long and narrow, whereas in *L. roseicremea* they are much shorter and narrowed toward the ends. These cuticular cells are borne at the ends of chains of subglobose cells. The microscopic details were obtained from the type. Macroscopically the two species are distinguishable by the annulus. In *L. illinita* it is glutinous and becomes obsolete. In *L. roseicremea* the annulus is membranous, ample, and persistent and may remain stretched from the margin to the stipe for some time. This species is known only from the type locality but appears to be a really distinctive *Limacella*.

7. *Limacella agricola* Murrill, Mycologia, 3: 81. 1911.

Pileus 2.5 cm. broad, convex, regular, rather firm, surface glabrous, smooth, white, slimy, margin incurved and striate; lamellae free, white, broad, unequal; stipe 2.5 cm. long, 2 mm. thick, slightly bulbous at the base, cylindric, even, white, glabrous, shining, annulus slight, evanescent, superior.

Spores 4-5  $\mu$  long, subglobose, smooth, perfectly hyaline, often. uninucleate; other microscopic characters not known.

*Habitat and distribution.* — On a lawn; Jamaica.

*Observations.* — This species is very poorly known. It is pure white and much smaller than most members of the genus. It has been reported only from the type locality in Jamaica, and, since no information is available on the character of the gill trama, further collections and studies are necessary in order to determine its relationships. Its inclusion here is provisional.

8. *Limacella roseola* Murrill, Mycologia, 35:426. 1943.

Pileus about 5 cm. broad, convex to expanded, umbonate, rose pink with a slightly darker umbo, surface smooth, glabrous; lamellae approximate to the stipe, rose-tinted, crowded, fairly broad, edges even; stipe about 7 cm. long, slender and tapering upward, pale roseous, subglabrous, annulus evanescent, median.

Spores globose to subglobose,  $3.5-4.8 \times 3-4 \mu$  in diameter, when immature appearing very finely punctate in mounts revived in chloral hydrate-iodine solution, pseudoamyloid (becoming rusty brown in the iodine solution); basidia  $16.8-25 \times 4.2-6.3 \mu$ , four-spored; neither cheilocystidia nor pleurocystidia differentiated; pileus trama loosely floccose beneath the cuticle but fairly compact toward the subhymenium, lactifers numerous, contorted and branched,  $4-6 \mu$  in width, staining brown in iodine solution, clamp connections present, hyphae of cuticle narrow ( $2-6 \mu$ ), the end cells often somewhat enlarged near the apex, more or less decumbent and not forming a distinct turf of upright hyphae; gill trama divergent from a central strand, with numerous contorted and branched lactifers  $6.3-12.6 \mu$  wide, which stain a deep rusty brown in iodine solution.

When dried the cap is avellaneous with a tinge of cinnamon on the disc. Dr. Murrill says the cuticular hyphae are slightly gelatinous in KOH. This indicates that the pileus is likely to be at least slightly viscid when wet.

*Habitat and distribution.* — Growing on humus in a hollow tree; Virginia.

*Observations.* — The pink color of the entire fruiting body should be a good field character for this species. Microscopically it is distinguished by the pseudoamyloid reaction of the spores in chloral hydrate-iodine solution. The spores become a deep rusty brown in iodine, a reaction somewhat paler than that usually noted in *Lepiota*. This is a character frequently observed among the true *Lepiotae*



but not among the species of *Amanita*. The lactifers are very conspicuous in the iodine mounts.

9. *Limacella lenticularis* (Lasch) Earle, Bull. New York Bot. Gard., 5: 447. 1909.

- Agaricus lenticularis* Lasch, Linnaea, 3 (18): 157. 1828.  
*Lepiota lenticularis* Gillet, Les Hyménomycètes, p. 66. 1874.  
*Amanitella lenticularis* Maire, Ann. Mycol., 11: 337. 1913.  
*Amanita lenticularis* Lange, Bot. Arkiv, 2 (3): 11. 1915.  
*Lepiotoopsis lenticularis* Konrad et Maublanc, Icon. Sel. Fung., Vol. I, pl. 9. 1924.  
*Lepiota guttata* Quélet, Champ. Jura et Vosges, Suppl. 4: 325. 1876.  
*Limacella guttata* Konrad et Maublanc, Icon. Sel. Fung., Vol. I, pl. 9. 1924.  
*Agaricus megalodactylus* Berkeley, Outl. Brit. Fungol., p. 91. 1860.  
*Amanita megalodactyla* Saccardo, Syll. Fung., 5: 20. 1887.  
*Lepiota lenticularis* var. *megalodactyla* Rea, Brit. Bas., p. 80. 1922.  
*Agaricus lerchei* Weinmann, Hymen. et Gast. Ross., p. 11. 1836.  
*Amanita* (subg. *Limacella*) *lenticularis* Gilbert, Le genre *Amanita* Persoon, p. 160. 1918.

Illustrations:

- Cooke, Illus. Brit. Fungi, No. 15, pl. 11 (as *Agaricus* [*Amanita*] *megalodactylus*).  
Fries, F. Icon. Hymen., pl. 13.  
Konrad et Maublanc, Icon. Sel. Fung., Vol. I, pl. 9 (as *L. guttata*).  
Lange, Flora Agar. Danica, Vol. I, pl. 7, fig. A.  
Smith, Pap. Mich. Acad. Sci., Arts, and Letters, 26 (1940), pl. 2. 1941.

Pileus 6–15 cm. broad, very obtuse when young, becoming broadly umbonate at maturity or the margin elevated slightly and the umbo disappearing, glabrous and viscid when young, in age the cuticle sometimes separating into fibrils and then appearing obscurely virgate, margin often splitting radially, cuticle sometimes subrimose, the exposed flesh appearing whitish, cuticle evenly “vinaceous buff” and remaining so throughout development, in age the disc often marked with roundish more or less watery spots, margin incurved and cottony-fibrillose when young; flesh white, thick (7–8 mm. near the stipe), unchanging, odor subfarinaceous when cut, taste mild or slightly fungoid; lamellae approximate to the stipe but free, very close (120–130 almost reach the stipe), many lamellulae present, broad (1 cm.), pure white until late maturity, then dull grayish to olivaceous gray, especially along the edges; stipe 10–15 cm. long, 1–2.5 cm. thick, solid, base somewhat enlarged into an oval bulb which is rounded underneath, conspicuously longitudinally appressed-fibrillose-striate above and below the superior membranous annulus,

neither scaly nor sheathed, interior pallid, the surface somewhat darker; annulus membranous, thin, sometimes evanescent, fibrillose on both surfaces, dull pale vinaceous gray, paler than the pileus.

Spores  $4-5 \times 3.5-4 \mu$ , white in mass, ellipsoid to subglobose, nonamyloid, smooth; basidia  $18-30 \times 4-6.5 \mu$ , four-spored, hyaline in KOH; cheilocystidia and pleurocystidia not differentiated; gill trama of divergent hyphae, hyaline in KOH; cuticle of pileus of more or less upright subgelatinous hyphae  $14-24 \times 4-5 \mu$ , the end cells attenuated to an obtuse point, more or less hyaline; pileus trama of hyaline floccose hyphae with clamp connections at the cross walls.

*Habit, habitat, and distribution.* — Gregarious to scattered under elm and ash in swamps; southern Michigan.

*Observations.* — *L. lenticularis* is the central species around which several others are grouped. It is apparently much more common in Europe than in North America, and is well described and illustrated in the European literature.

*Limacella lenticularis* var. **Fischeri** (Kauffman),  
comb. nov.

*Lepiota Fischeri* Kauffman, Agar. Mich., I: 630. 1918.

Illustration:

Kauffman, *op. cit.*, Vol. II, pl. CXXVII.

Pileus 4-9 cm. broad, convex-campanulate, obtuse, even, subviscid with a separable cuticle, white to pale alutaceous, flesh thick, white, and soft, taste slight, odor becoming strong on drying (like that of *Tricholoma sulfureum*), lamellae crowded, rather narrow, plane, white, free and somewhat remote, edge entire; stipe 4-10 cm. long, 4-10 mm. thick, subbulbous, striate, fibrillose, fibrous-fleshy, solid, firm, separable from the pileus, annulus large, superior, white and fragile, subpersistent, at length pendulous.

Spores subglobose to oval,  $3.5-5.6 \times 4.5-6.6 \mu$  (according to Kauffman,  $3-4 \times 2-3 \mu$ ), with a distinct apiculus, very pale yellow in chloral hydrate-iodine solution (very few spores now present in the type); basidia  $15-21 \times 3.4-6.2 \mu$ , sterigmata few, three seen on one basidium (according to Kauffman, there are usually 1-2, rarely 3-4, and they measure  $5-7 \mu$  long); neither pleurocystidia nor cheilocystidia present; gill trama compact and divergent; pileus trama homogeneous and fairly compact under a pellicle consisting of

upright more or less irregular blunt-pointed slightly differentiated hyphal tips 15–30  $\mu$  long and 4–5  $\mu$  in diameter, their gelatinous nature not readily visible when revived in KOH.

*Habit, habitat, and distribution.* — Gregarious on leaf mold or on the ground in low frondose woods. It has been found in Ontario, Canada, and in Michigan and Pennsylvania in the United States.

*Observations.* — The type, which has been examined, has very few spores. They measure  $3.5\text{--}5.6 \times 5.5\text{--}6.6 \mu$ . Several additional collections identified by Kauffman were also present among his collections and were found to have the same size spores as the type. Consequently the strong odor on drying and the absence of green drops or olivaceous discolorations are left as the principal differences between var. *typica* and var. *Fischeri*. These do not appear sufficient to justify maintaining Kauffman's fungus as a distinct species, particularly in the light of the pronounced similarities of the two in all other respects. *L. solidipes* is distinguished by its strongly farinaceous odor and taste and paler colors when fresh. In the dried condition, however, all three have become about the same shade of pinkish buff.

### 10. *Limacella solidipes* (Peck), comb. nov.

*Lepiota solidipes* Peck, Bull. New York State Mus., 5: 647. 1899.

*Limacella McMurphyi* Murrill, Mycologia, 4: 213. 1912.

Pileus 3–7 cm. broad, broadly convex to plane, viscid when moist, white at first but gradually becoming "pale pinkish buff" (very pale alutaceous), surface subrimose in age but never fibrillose or scaly, always opaque and dull; flesh white,  $5 \pm$  mm., tapering to margin, rather firm in consistency, odor and taste strongly farinaceous, lamellae crowded, attached to the stipe by a narrow tooth or simply approximate, edges even, no color change; stipe 8–10 cm. long, 10–12 mm. thick, equal, solid, firm, base sometimes slightly enlarged, surface glabrous above the annulus and beaded with hyaline drops, sparsely fibrillose below with scattered innate fibrils, never scaly; annulus superior, white and persistent, ample and pendulous.

Spores subglobose to globose,  $4 \times 5 \mu$  or  $4\text{--}5 \mu$  in diameter, with a definite apiculus, very slightly yellow in iodine; basidia  $19\text{--}32 \times 4.5\text{--}6 \mu$ , four-spored; neither pleurocystidia nor cheilocystidia differentiated; gill trama divergent from a central strand of fairly

large cells, subhymenium of small compactly arranged cells, hyaline in KOH; pileus trama with a distinctly differentiated cuticle of upright septate hyphae with distinctive rather blunt-pointed end cells, which taper somewhat like the filaments of *Rivularia*, the walls somewhat gelatinous; gill trama floccose-filamentous, becoming more compact toward the hymenium, cells about equal in width (3–8  $\mu$  in diameter), hyaline in KOH, clamp connections present.

*Habitat and distribution.* — Growing on humus under alder on swampy ground or among leaves under redwoods; New York, California, and Washington.

*Observations.* — *L. solidipes* is very closely related to *L. lenticularis* but can readily be distinguished by its white pileus, at least on young fresh specimens, and by the strong farinaceous odor and taste. Although the stipe above the annulus was beaded with drops of moisture, there is no indication that these ever assume olivaceous tints. *L. McMurphyi*, which also has a farinaceous odor and taste, is tentatively referred here, since no distinctions between the two are evident from the information available. As yet the type of the latter has not been sectioned to verify its position in this genus. Dried specimens of *L. solidipes* and *L. lenticularis* have much the same appearance.

11. *Limacella glioderma* (Fr.) Earle, Bull. New York Bot. Gard., 5: 447. 1909.

*Agaricus (Lepiota) gliodermus* Fries, Monogr. Hymen., 1: 31. 1857.

*Lepiota glioderma* Gillet, Les Hyménomycètes, p. 73. 1874.

*Armillaria glioderma* Quélet, Champ. Jura et Vosges, Suppl. 3 (113): 541. 1875.

*Gyrophila glioderma* Quélet, Enchir. Fung., p. 9. 1886.

*Amanitella glioderma* Maire, Ann. Mycol., 11: 337. 1913.

*Amanita* (subg. *Limacella*) *glioderma* Gilbert, Le genre *Amanita* Persoon, p. 167. 1918.

*Melanoleuca subpessundata* Murrill, Mycologia, 5: 222. 1913.

*Tricholoma subpessundatum* Murrill, Mycologia, 5: 223. 1913.

*Limacella subpessundata* Singer, Lloydia, 5: 132. 1942.

*Melanoleuca subvelata* Murrill, Mycologia, 5: 222. 1913.

*Tricholoma subvelatum* Murrill, Mycologia, 5: 223. 1913.

*Armillaria graveolens* Murrill, Mycologia, 35: 422. 1943.

Illustrations:

Plate I.

Fries, Icon. Hymen., pl. 15, no. 1.

Pileus 3–8 cm. broad, obtuse when young, the margin incurved slightly, becoming nearly plane with a very low broad umbo, in age

the margin may be broadly recurved, surface with a thin coat of gluten when young, becoming merely viscid and with a dry granulose appearance under a lens, later breaking up into crustose patches which show the pale flesh beneath, cuticle "carb brown" to "chestnut brown" when young, becoming paler and near "onion skin pink" on the margin and "cameo brown" near the darker disc (dark reddish or chestnut brown fading to pale vinaceous brown); flesh thick on the disc, thin elsewhere, very soft and fragile, whitish but tinged pale vinaceous, odor and taste very strongly farinaceous; lamellae close but distinct, approximate to the stipe or attached by a tooth, 35-37 just about reach the stipe, 1-2 tiers of lamellulae, broad (5-10 mm.), becoming ventricose, whitish at first, becoming "pale pinkish buff," edges even or slightly fimbriate; stipe 5-9 cm. long, 5-10 mm. thick, solid or hollow, equal or tapering slightly above, surface pallid above and glabrous to appressed-silky, with "fawn color" to "light vinaceous cinnamon" zones of fibrils below formed from the veil, no membranous annulus, dry over all or viscid when gluten from the cap has dropped on it.

Spores globose or subglobose, 3-4  $\mu$  in diameter or occasionally up to 5  $\mu$ , not amyloid or old spores sometimes pseudoamyloid; basidia four-spored, often projecting when sporulating, 16-22  $\times$  5-7  $\mu$ ; pleurocystidia and cheilocystidia not differentiated; gill trama clearly divergent from a central strand, subhymenium parenchymatous, clamp connections present; cuticle of pileus gelatinous, the cells somewhat interwoven and more or less erect (as seen in liquid mounts of sections), 2-4.5  $\mu$  in diameter and about 30  $\mu$  long, tapering to a point; pileus trama floccose and loosely organized.

*Habit, habitat, and distribution.* — Single, scattered to gregarious, on rich humus under hardwoods or conifers. In North America it is known from Nova Scotia and Ontario in Canada, and from Florida, Maryland, New York, Michigan, Washington, and Oregon in the United States. It is one of the two relatively common species of *Limacella*. It usually fruits during the late summer and fall.

*Observations.* — Singer (1942) first recognized that *Tricholoma subvelatum* and *T. subpessundatum* belong in *Limacella* and are conspecific. I have collected the fungus in considerable abundance along the west coast of the United States, but have been able to distinguish only the one species. Its colors vary much in intensity, but from the information available there appear to be no distinct color

forms and, as a result of a study of Murrill's types, no characters have been found to separate his species from *L. glioderma*. The colors of the dried carpophores of *Armillaria graveolens* are slightly more brownish than is typical for *L. glioderma*. This difference and Murrill's description of the color of the fresh cap as isabelline may indicate the presence of a distinct southern form in our flora. The point, however, needs careful study of more material than is available at present. In all the fresh material I have studied the odor and taste were very pronounced and constant, and no forms with a mild taste were collected. The fruiting bodies photographed were rather large. Plate I shows the cuticle pulling back from the margin of the pileus in the cap at the left. This causes old caps to have a ragged appearance.

12. *Limacella delicata* (Fries) Earle, Bull. New York Bot. Gard., 5: 447. 1909.

*Agaricus (Lepiota) delicatus* Fries, Syst. Mycol., 1: 23. 1821.

*Lepiota delicata* Gillet, Les Hyménomycètes, p. 73. 1874.

*Armillaria delicata* Boudier, Icon. Mycol., 1: 12. 1905.

*Amanita* (subg. *Limacella*) *delicata* Gilbert, Le genre *Amanita* Persoon, p. 168. 1918.

Illustrations:

Boudier, Icon. Mycol., Vol. I, pl. 23.

Fries, Icon. Sel. Hymen., pl. 15, no. 2.

Pileus 2-8.4 cm. broad, campanulate, convex or obtuse, sometimes with a very large obtuse umbo, the margin at times somewhat elevated and finally wavy, opaque, pale to rather dark brownish red, the margin incarnate brownish, glabrous, cuticle subviscid when wet, then becoming dull and unpolished; flesh thick on the umbo, thin at the margin, white or more or less hyaline, but mostly concolorous with the cuticle near the surface, odor slightly of green wood, not at all farinaceous; lamellae white or milk white, not very crowded, 44-48 reach the stipe, 1-3 tiers of lamellulae, more or less ventricose, narrowly adnexed, then free or remaining attached by cobwebby filaments, lamellulae not truncate toward the stipe; stipe 2.5-5 cm. long, 3-6 mm. thick, subequal or slightly attenuated downward, evidently tinted rosy-flesh color, base more or less whitish, annulus absent or present as woolly fibrillous zones or floccules scattered over the lower portion, solid or stuffed, flesh soft, brittle, cream color.

Spores round, 4–5  $\mu$  in diameter, smooth, with an abrupt apiculus, white in mass; basidia 25–30  $\times$  5.5–6.2  $\mu$ ; gill edges provided with numerous claviform hairs 8–9  $\mu$ , with clamp connections; gill trama bilateral, hyphae diverging regularly and appearing more or less cellular between the central strand and the subhymenium; cuticle of pileus of erect gelatinous hyphae with clamp connections, elongated, 4–6  $\mu$  in diameter, mostly colorless but some with oily yellow contents, the brown pigment located in the hypoderm in the form of irregular plates incrusting the hyphae.

*Distribution.* --- This species is at present not definitely known to occur in North America.

*Observations.* --- The description is translated and adopted from Kühner (1936). Small fruiting bodies answering the description given above in nearly all respects are not uncommon among the collections of Kauffman and A. H. Smith in the University of Michigan Herbarium, but no record of their taste is available. Consequently the presence of *L. delicata* in North America has not been established, although I suspect that it occurs here. It was reported by some of the early investigators. Aside from the small size, the lack of a farinaceous taste is about the only character which would distinguish *L. delicata* from *L. glioderma*. Kühner (1936) has suggested that they may be merely varieties of a single species.

#### EXCLUDED AND DOUBTFUL SPECIES

*LEPIOTA IRRORATA* Quélet-Rea. — A true *Lepiota* (Kühner, 1936).

*LEPIOTA RUBIDA* Kauffman. — Placed in the *Viscidiae* of *Lepiota* by Kauffman, who stated that it has regular gill trama, a fact confirmed by an examination of his material. It is, therefore, a true *Lepiota*.

*LIMACELLA ALBISSIMA* Murrill. — This is *L. pulcherrima* Graff, and is a true *Lepiota* with regular gill trama.

*LIMACELLA BENTISTA* (Morgan) Murrill. — Tentatively excluded because of the large spores. A study of the gill trama is necessary to determine exactly where this species should be placed.

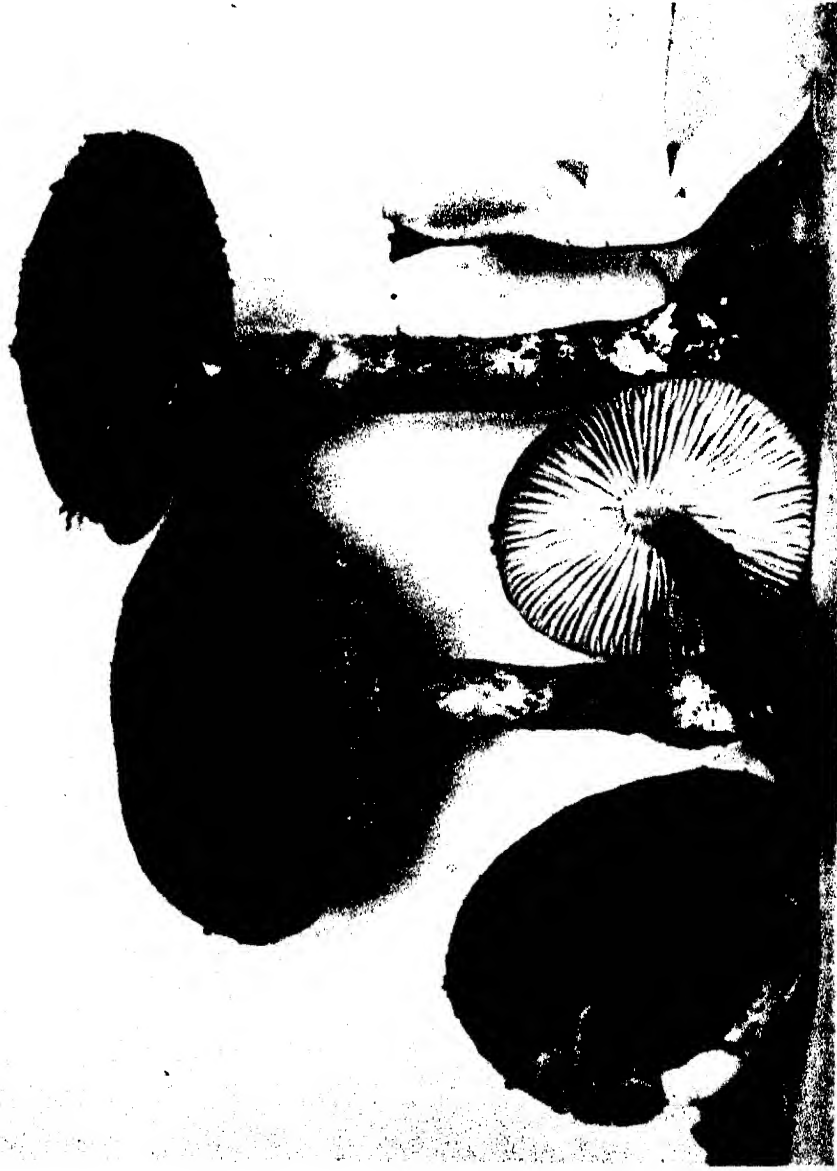
*LIMACELLA FULVODISCA* (Peck) Murrill. — A study of the type shows that this has regular gill trama and is, therefore, a true *Lepiota*.

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**PLATE 1**



*Limacella gladiatoria* (Fries) Earle.  $\times 1$



# A PERFORATING SPECIES OF ECTOCHAETE (HUBER) WILLE FROM THE GALÁPAGOS ISLANDS

FRANCESCA THIVY

**A**N UNDESCRIBED alga appears among the perforating Chlorophyceae found in dead shells and worn coral specimens in the collections of the Hancock Galápagos Expedition of 1934. It forms a rich growth in the outer layers of a large shell. In its sporangia and individual filaments it resembles the perforating alga *Phaeophila Engleri* Reinke, but it has a distinguishing habit and is also different in the number of nuclei to a cell. Staining with acetocarmine immediately after decalcification with 2 per cent glacial acetic acid showed uninucleate cells (Pl. I, Figs. 18-20). This result could usually be seen about thirty-six hours after staining. It was found, by the use of the same stain, that *P. Engleri* Reinke and *P. dendroides* (Crouan) Batters have predominantly multinucleate cells. This character proves decisively that the alga is a species of *Ectochaete* (Huber) Wille, the concept of which, like that of the closely allied genus *Entocladia* Reinke (Kylin, 1935, pp. 197, 201), would now include the perforating habit of growth.

## *Ectochaete* (Huber) Wille, 1909

(Plate I)

Möbius, 1891, p. 1292, pl. XIV, figs. 1-10; Huber, 1892a, p. 331, fig. 5; 1892b, pp. 319-326, pl. XV, figs. 1-17; Batters, 1902, p. 14; Wille, 1909, p. 79; Heering, 1914, pp. 97-98; Børgesen, 1920, pp. 418-419, fig. 400; Oltmanns, 1922, I: 299-300; Printz, 1927, p. 194; Hamel, 1930, p. 28; Newton, 1931, p. 62; Feldmann, 1937, p. 181; Taylor, 1942, pp. 15-16; Thivy, 1942, pp. 97-109; 1943, pp. 250-258.

A marine or fresh-water genus, endophytic between the wall layers or in the slime of larger algae, or perforating in shells; thalli consisting of discs of radiating or congested, free or partly fused filaments; branching lateral, at times subdichotomous; cells cylindrical to round, setigerous, uninucleate with a parietal platelike, rarely

perforate, chloroplast, containing starch granules and 1-8 pyrenoids; seta tubular, straight, usually occurring singly, without a basal septum, or occasionally with the lumen at the base nearly obliterated by a simple increase in thickness of the wall or by an annular thickening, or at times partitioned by a secondary septum; plants reproducing by biflagellate zoospores and gametes, each with a chloroplast, a pyrenoid, and an eyespot; germination direct, taking place either by the production of a germination tube from the anterior end of the zoospore, in a line with its long axis, or without it, but by the formation of filaments in one or more directions more or less perpendicular to the long axis of the zoospore.

**Ectochaete perforans**, sp. nov. — Plant forming a dense growth in the prismatic layer of dead shells, composed of closely packed, free, laterally branched filaments, with the basal septum of a branch usually placed a little above the branch insertion; cells cylindrical, short to very long, uninucleate, with a platelike parietal, homogeneous to granular chloroplast, containing starch and frequently one or, rarely, 2-3 pyrenoids, often setigerous or sometimes with a small incrassate knob on the wall; intercalary cells usually 7-20  $\mu$  in diameter, the length 1.3-4.0 times the diameter, up to 43  $\mu$ , often with a lateral lobe, here and there constricted-rhizoidal when the cell is 3  $\mu$  in diameter; terminal cells 7-13  $\mu$  in diameter, length 3-9 times the diameter, from 20 to 95  $\mu$ ; seta straight, continuous with the lumen of the cell but at times with a basal secondary septum or annular thickening of the wall, single or, extremely rarely, two to a cell, 2.0-3.8  $\mu$  in diameter, the length reaching 50  $\mu$ ; sporangia as a rule intercalary, 7-28  $\mu$  in diameter, the length 1.5-2.5 times the diameter, from 17 to 38  $\mu$ , with about 12 zoospores of 3.5-8.0  $\mu$  diameter showing a nucleus, a chloroplast, a pyrenoid, and an eyespot; emission tube 3.5-5.0  $\mu$  in diameter, up to half as wide as the sporangium, usually slightly narrower than the diameter of the zoospores, in length mostly 1-3 times the height of the sporangium but up to 29  $\mu$ , very rarely absent; aplanosporangia rare, with aplanospores about 8  $\mu$  in diameter.

Galápagos Islands: Isabela I., in dead shells in tide pools at Cartago Bay, *W. R. Taylor 34-352E*, January 25, 1934.

The shell is conical, 10 cm. long and 6.5 cm. in diameter at the wider end. The alga described here is embedded to some depth, chiefly in the outer face of the shell, along with *Hyella caespitosa*

B. & F., whereas in the same shell *Pilinia maritima* (Kjellm.) Rosenv., forma nova *pacifica* (inedit.), occurs in the outermost part.

*Ectochoete perforans*. — Thallus in stratum prismaticum concharum perforans, e filamentis ramosis, confertis, non coniunctis compositus; cellulis uninucleatis, pyrenoideis plerumque uno, infrequenter 2-3, praeditis, saepe unam setam (vel rarissime duas) gerentibus; setis 2.0-3.8  $\mu$  crassitudine, rectis, non basi septatis sed interdum aut ad basim incrassatione parietali annuliformi aut septo basali secundario instructis; cellulis intercalaribus 7-20  $\mu$  crassis, 1.3-4-plo longioribus quam crassioribus, longitudine minus quam 43  $\mu$ , passim radiciformibus, angustis, circa 3  $\mu$  crassitudine; cellulis terminalibus 7-13  $\mu$  crassitudine, 3-9-plo longioribus quam crassioribus sed inter 20 et 95  $\mu$ ; sporangiis plerumque intercalaribus 7-28  $\mu$  crassis, 17-38  $\mu$  longis, circa 12 zoosporas includentibus, ostiolo tubuliformi 3.5-5.0  $\mu$  crasso, 3.5-29  $\mu$  longo. Specimina typica legit W. R. Taylor, no. 34-352E, in loco dicto Cartago Bay, I. Isabela, in Insulis Galapagorum.

As found in the decalcified material, the chloroplast was generally homogeneous (Figs. 1, 3, especially) and extraordinarily thin and translucent, but at times granular, yet still thin; in either condition starch was present. A fraction of the cells had pyrenoids, which became visible only on staining. In a large number of the setae a secondary septum was seen (Figs. 8-9), and a preceding step in its development was observed in the clear plasma membrane, which occurred frequently across the opening of the seta (Fig. 7). In setae remaining open at the base a plasma membrane is not visible (Figs. 1, 5, especially). In this genus the seta at first has a cytoplasmic lining continuous with that of the cell (Huber, 1892a, p. 331, fig. 5; 1892b, p. 321, pl. XV, fig. 3), later it practically disappears in the seta, but no visible plasma membrane or wall has been noticed across the base of the seta in the other species. Very rarely the sporangium either has a papillate process (Fig. 17) or does not develop an emission tube, an opening being formed directly in the wall (Fig. 17).

The outer branches, which are crowded and are either unicellular and very long or two- to four-celled, each with a very long terminal cell (Figs. 1-2, 19-20), are distinctive of the species. By comparison with that characterizing the other species, in *Ectochoete perforans* the ratio of the diameter of the emission tube to that of the sporangium is, on the whole, smaller (Figs. 11-16).

In the genus reproduction by aplanospores (Fig. 21) has been observed only in *Ectochaete perforans*. *Phaeophila Engleri* (Thivy, 1943, pl. I, fig. 8), which is a perforating form, has been found to have these spores. This suggests that this method of asexual multiplication is an adaptation to the frequently deep penetration of these algae. The scattered attenuate rhizoidal intercalary cells (Fig. 10) no doubt serve the purpose of boring into the hard layers of shells.

A key to *E. leptochaete* (Huber) Wille, *E. Taylori* Thivy, and *E. endophytum* (Möbius) Wille was previously given (Thivy, 1942, p. 98), but no specimens of *E. leptochaete* had been seen by the writer till the species was found at Woods Hole, Massachusetts, in the summer of 1942. With a better knowledge of this species the presence of a few setae, which was considered characteristic of it, is found to be only a variable feature, for in some discs many appear. A closer study of the marine species has shown, besides, that *Endoderma vagans* Børgesen is an *Ectochaete* because it produces setae and that the genus possesses considerable plasticity of habit, and of seta (Figs. 6, 8; Thivy, 1943, pp. 256-258) and sporangium structure, grows in varied substrata, and has a wide distribution. Like *Acrochaete repens* Prings. and *P. Engleri*, one among the endophytic species, and the perforating species of *Ectochaete* establish contact with the water by means of incrassate processes on their cell walls (Figs. 3-4), as well as by setae. The increasing interest of botanists in the genus justifies the provision of a fuller key to its species.

#### KEY TO THE SPECIES OF ECTOCHAETE

- |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                     |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|
| 1. Marine .....                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 2                   |
| 1. Fresh water .....                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 5                   |
| 2. Endophytic in cell wall or slime of larger algae; emission tube wide, its diameter one to several times that of zoospores, 0.5-1.0 times diameter of sporangium .....                                                                                                                                                                                                                                                                                                                                                                                                                                  | 3                   |
| 2. Perforating in shells; emission tube narrow, usually of slightly smaller diameter than that of zoospores, up to 0.5 times the diameter of sporangium, length up to 3 times the diameter of sporangium; filaments free, in various planes, crowded; cells usually 7-20 $\mu$ in diameter, length 1.3-4.0 times the diameter, within 43 $\mu$ ; terminal cells 7-13 $\mu$ in diameter, length 3-9 times the diameter, from 20 to 95 $\mu$ ; setae 2.0-3.8 $\mu$ in diameter, seen with difficulty; pyrenoids 1-3; sporangia 7-28 $\mu$ in diameter, length 1.5-2.5 times the diameter, 17-38 $\mu$ ..... | <i>E. perforans</i> |
| 3. Endophytic in the outer cell walls of the host, thallus disclike, filaments predominantly in one plane; setae 1.0-1.5 $\mu$ in diameter and inconspicuous; cells usually 5-15 $\mu$ in diameter .....                                                                                                                                                                                                                                                                                                                                                                                                  | 4                   |

3. Endophytic in slime binding the cortical filaments of host; thallus matted, punctiform; filaments in various planes, mostly free; setae 3-4  $\mu$  in diameter, conspicuous; cells usually 8-18  $\mu$  in diameter, length usually 1-3 times the diameter, up to 33  $\mu$ ; pyrenoids 1-8; sporangia 9-13  $\mu$  in diameter, length 1.0-3.5 times the diameter, up to 39  $\mu$ ; emission tube in length 0.3-5.0 times the diameter of the sporangium ..... *E. Taylori*
4. Discs distinctly pseudoparenchymatous, outer branches not widely spreading; central cells 5-15  $\mu$  in diameter, length 1.0-1.5 times the diameter, up to 15  $\mu$ ; outer cells usually longer, 4-5  $\mu$  in diameter, length 2-4 times the diameter, up to 18  $\mu$ ; cells without incrassate process on wall; setae 1.0-1.5  $\mu$  in diameter, seen with difficulty, base not incrassate-conical; pyrenoids 1-4; sporangia 5-12  $\mu$  in diameter, roundish; length of emission neck 0.3-0.5 times the diameter of the sporangium, without incrassate wall ..... *E. leptochaete*
4. Disc very slightly or not pseudoparenchymatous, outer branches widely spreading; central cells usually 5-10  $\mu$  in diameter, length 1-4 times the diameter, up to 30  $\mu$  (at times said to reach 13  $\mu$  in diameter); outer cells usually much longer, 1-5  $\mu$  in diameter, length 5-17 times the diameter, up to 80  $\mu$ ; cells often with incrassate process on wall; setae about 1  $\mu$  in diameter, seen with very great difficulty, base incrassate-conical; pyrenoids 1-7; sporangium usually 9-11  $\mu$  in diameter, length about 1.5 times the diameter; emission neck as in previous species, but usually with incrassate wall ..... *E. vagans*
5. Endophytic in walls of filamentous green algae; thallus dislike, pseudoparenchymatous, later breaking through host wall and forming pulvinate mass of fused spherical cells; cells 8-20  $\mu$  in diameter, length 1-5 times the diameter; setae firm, refringent; sporangia roundish; length of emission neck about equal to diameter of sporangium .... *E. endophytum*

The writer is greatly indebted to Professor William R. Taylor, of the University of Michigan, for the opportunity of studying the perforating Chlorophyceae represented in the collections made by him as botanist of the Hancock Expedition of 1934.

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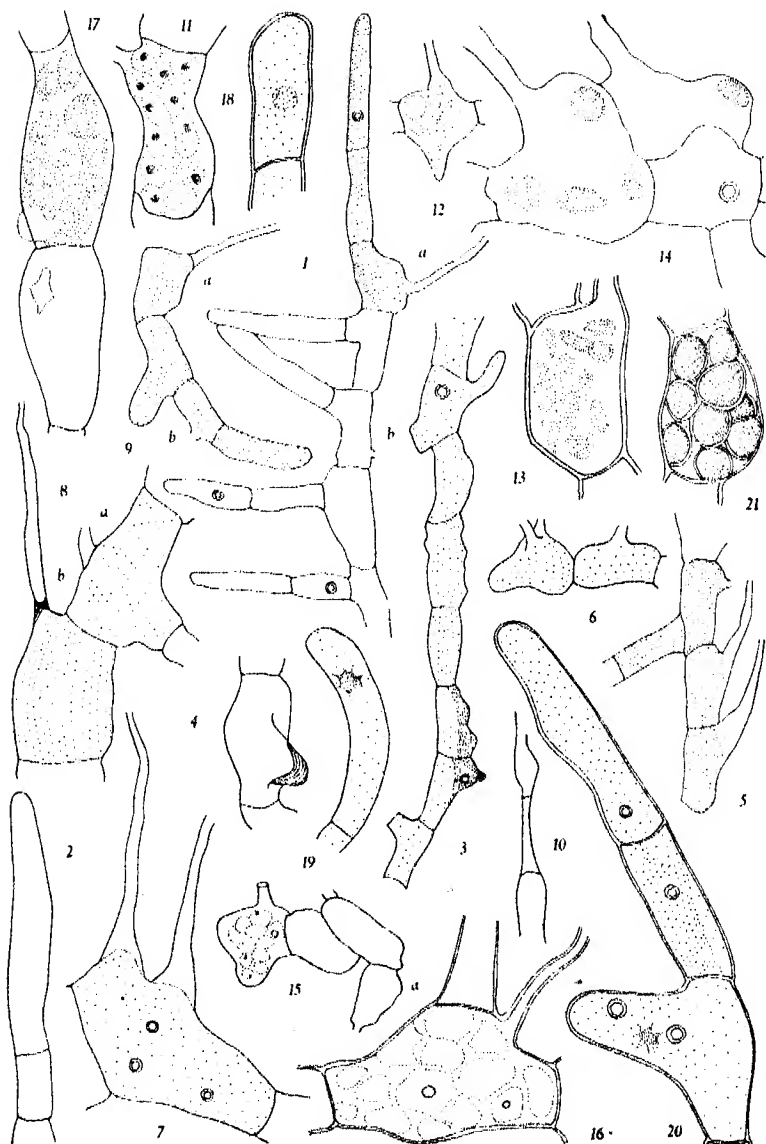
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## PLATE I

## EXPLANATION OF PLATE I

### *Ectochaete perforans*, sp. nov.

- FIG. 1. Outer filament showing the basal septa of branches, two setigerous cells at *a* and *b*, and terminal cells.  $\times 761$
- FIG. 2. Filament with a very long terminal cell.  $\times 352$
- FIG. 3. Filament showing two cells with sinuous walls and one with an incrassate knob on wall.  $\times 352$
- FIG. 4. Cell with a process capped by an incrassate knob on wall.  $\times 440$
- FIG. 5. Filament showing three setae without basal septa.  $\times 352$
- FIG. 6. Two setigerous cells, one with two setae.  $\times 385$
- FIG. 7. Cell showing two setae with clear plasma membranes across their bases.  $\times 761$
- FIG. 8. Filament showing a seta with a secondary basal septum at *a*, and another with a basal annular thickening of the wall at *b*.  $\times 761$
- FIG. 9. Filament showing a lobed cell and two setigerous cells at *a* and *b*, the seta at *a* having a secondary basal septum.  $\times 352$
- FIG. 10. Filament showing an intercalary, constricted, rhizoidal cell.  $\times 352$
- FIG. 11. Sporangium showing a nucleus in all but one of the zoospores, stained with acetocarmine.  $\times 761$
- FIG. 12. Lobed sporangial cell.  $\times 352$
- FIG. 13. Sporangium; zoospores about  $3.5\ \mu$  in diameter, emission tube  $4.7\ \mu$  in diameter.  $\times 761$
- FIG. 14. Filament with two sporangia; zoospores  $4.7$ – $5.8\ \mu$  in diameter, emission tube  $4.7\ \mu$  in diameter.  $\times 761$
- FIG. 15. Filament with two sporangia, the one at *a* empty; in the other three zoospores showing one eyespot each and one a pyrenoid; zoospores  $5.9$ – $8.2\ \mu$  in diameter, emission tube  $3.5\ \mu$  in diameter.  $\times 352$
- FIG. 16. Sporangial cell with a emission tube  $3\ \mu$  in diameter and a wider branch cell; divisions of protoplast  $2.3$ – $6.0\ \mu$  in diameter, the pyrenoid seen in two of them.  $\times 761$
- FIG. 17. Two sporangia, the empty lower one showing an opening directly in the wall, the upper with a papillate process, shown by broken line.  $\times 761$
- FIGS. 18–19. Two vegetative cells showing the single nucleus, stained with acetocarmine.  $\times 761$
- FIG. 20. Filament showing terminal cell and pyrenoids; one cell showing nucleus, stained with acetocarmine.  $\times 761$
- FIG. 21. Aplanosporangium with aplanospores surrounded by cell walls.  $\times 761$



*Ectochaete perforans*, sp. nov.



## NEW AND UNRECORDED MARINE ALGAE OF HONG KONG \*

CHENG KWEI TSENG

**A**LTHOUGH the marine algae of Hong Kong have been studied by various phycologists for over a hundred years, the number of species reported is pitifully small. In 1940 the writer published a list of seventy-eight species definitely known to be represented in this region. In subsequent papers (Tseng 1941, 1942, 1943 a-b, 1944 a-c) he has added thirty species to the floristic list of Hong Kong, including thirteen newly described. Further studies have revealed the occurrence of many species that have not previously been reported from this region, some of which are believed to be new. The present paper is a report of the studies on several of these marine plants.

### 1. *Acrochaetium crassipes* (Børg.) Børg.

Børgesen, Marine Algae of the Danish West Indies, II, i, 1915, p. 20, fig. 11;  
*idem*, Some Indian Rhodophyceae, 1931, p. 2, fig. 1.  
*Chantransia crassipes* Børg., West Indian Florideae, I, 1909, p. 1.

Small epiphytic algae up to about 70  $\mu$  high. Basal cell shortly subcylindrical or barrel-shaped, with a rather thick wall about 10  $\mu$  in diameter, fastening to the surface of the host by a rather thick layer of cementing substance. Erect filaments often unilaterally branched, more or less curved and decumbent, largest near the base, tapering toward the summit, where the cells are only about 3  $\mu$  in diameter. Hairs seldom present. Cells about as long as broad, constricted at the transverse walls, each with a single axial, stellate chromatophore having a central pyrenoid. Monospores oval to obovate, about 5  $\mu$  broad and 6 to 7  $\mu$  long. Sexual organs unknown.

*Habitat.* — On *Polysiphonia* from Panglongwan, Port Shelter, in March (*Taam A68a*).

*Distribution.* — St. Thomas, West Indies (type locality), and Dwarka, India.

\* Papers from the Department of Botany of the University of Michigan, No. 742.

## 2. *Acrochaetium arcuatum* (Drew), comb. nov.

(Plate I, Figure 1)

*Rhodochorton arcuatum* Drew, A Revision of the Genera Chantrelle . . . , 1928, p. 165, pl. 37, figs. 1-3.

Small epiphytic algae up to about 120  $\mu$  high. Basal cell globular or subglobular, about 10 to 12  $\mu$  in diameter, almost twice as large as the other cells above. Erect filaments two or three from the same basal cell, sometimes four, unilaterally or alternately branched (Pl. I, Fig. 1). Cells more or less barrel-shaped, 5 to 10  $\mu$  in diameter, one to two times as long, each with a single stellate chromatophore having a central pyrenoid. Monosporangia oval, terminal, or lateral, 6 to 8  $\mu$  broad, 8 to 12  $\mu$  long. Spermatangia not found; carpogonia still unknown.

*Habitat*. -- On Chaetomorpha from Shek-O, Hong Kong I., in December (Tseng 258a; Taam A13a).

*Distribution*. -- Moss Beach, San Mateo County, California (type locality); from Cape Flattery, Washington, southward to central California.

## 3. *Acrochaetium robustum* Børg.

(Plate I, Figures 2-4)

Børgesen, Marine Algae of the Danish West Indies, II, i, 1915, p. 40, figs. 38-40; II, vi, 1920, p. 449, fig. 418.

*Rhodochorton robustum* (Børg.) Nakamura, Species of *Rhodochorton* from Japan, I, 1941, p. 284, figs. 10-13.

*Acrochaetium sargassicolum* Børgesen, Some Indian Rhodophyceae, II, 1932, p. 115, figs. 3-5.

Bushy epiphytic algae up to 2 mm. or more high. Basal cell subcylindrical-oblong, conspicuously constricted in the middle, the lower half being embedded in the host tissue, about 12 to 15  $\mu$  broad, 15 to 28  $\mu$  long (Pl. I, Fig. 2). Erect filaments solitary, sometimes two, from the same basal cell, profusely, irregularly, laterally branched, with a greater tendency to unilaterality (Pl. I, Fig. 3). Cells subcylindrical, 6 to 11  $\mu$  broad, larger below, smaller above, two to three times as long as broad below, up to as much as four to six times longer than the breadth near the summit. Chromatophore parietal, with a large protruding pyrenoid. Monosporangia ellipsoidal, sessile or pedicellate, lateral or terminal, about 11 to 12  $\mu$  broad, 17 to 20  $\mu$  long (Pl. I, Fig. 3). A tetrasporangium

found only once, sessile and lateral on a branchlet (Pl. I, Fig. 4). Spermatia and carpogonia not found.

*Habitat.* — Abundant on Sargassum, covering almost the entire plant body, from Cape d'Aguilar (*Tseng* 2690) and Stanley Beach (*Taam* A68), both on Hong Kong I., in March.

*Distribution.* — Bombay, India (type locality).

#### 4. *Dermonema gracilis* (Mart.) Schmitz

(Plate I, Figures 5-6)

Schmitz, in Heydrich, Beiträge . . . Algenflora von Ost-Asien, 1894, p. 289; Weber-van Bosse, Liste des algues du Siboga, II, 1921, p. 204; Børgesen, Marine Algae of Ceylon, 1936, p. 80; *idem*, South Indian Marine Algae, 1937, p. 320.

*Gymnophloea gracilis* Martens, Die Tange, 1866, p. 146; Kützinger, Tabulae phycologicae, XVII, 1867, pl. 1.

*Dermonema dichotomum* Harv., Algae from Ceylon, No. 93 (*nomen nudum*); Schmitz und Hauptfleisch, Helminthocladiaceae, 1897, p. 335, fig. 205.

Fronde caespitose, attached by large discoid holdfast, profusely dichotomously branched in all directions, up to 6 cm. high. Branches terete or subcompressed near the base, about 2 mm. broad. Axial filaments about 5 to 7  $\mu$  in diameter. Assimilatory filaments once or twice dichotomously branched, with a large basal cell about 15 to 20  $\mu$  in diameter. Peripheral cells obovate, much swollen at the apices, about 10 to 16  $\mu$  in diameter at the broadest portion. The two or three cells below them much smaller, about 4 to 6  $\mu$  in diameter. Dioecious. Spermatangia in groups of two to four at the tips of the spermatangial cells, which form whorls around the narrow cells just below the large terminal cells (Pl. I, Fig. 5). Carpogonial filament 3-celled, more or less curved, although sometimes perfectly straight, lateral on the basal cell of the assimilatory filaments, about 10 to 20  $\mu$  broad (Pl. I, Fig. 6). Cystocarps not found. Color yellowish to dark purple.

*Habitat.* — Caespitose on exposed rocks in the littoral region, Hong Kong I.; Shek-O, from December (*Taam* A11) to March (*Tseng* 654, 2659) and Big Wave Bay, in April (*Tseng* 2706); Pang-longwan, Port Shelter, in March (*Taam* A61); and Lemma I., in May (*Taam* A118).

*Distribution.* — Calle, Ceylon (type locality); Formosa; New Guinea and Cape Comorin, South India.

This species is very common in the Hong Kong region in places



exposed to strong surf action. It is a spring annual, occurring in the period from December to May, when it begins to turn yellowish and soon dies off. It entirely disappears at the end of May. The materials collected show good spermatangia and carpogonia, but the writer never had any success in finding the peculiar development of the cystocarps described and illustrated by Schmitz, *op. cit.*

#### 5. *Fosliella farinosa* (Lamx.) Howe

Howe, Bahama Algae, 1920, p. 587; Taylor, Marine Algae of Northeastern . . . North America, p. 270.

*Melobesia farinosa* Lamouroux, Histoire des polypiers coralligènes flexibles, 1816, p. 315, pl. 12, fig. 3; Hauck, Meeresalgen, 1885, p. 263, fig. 107; Lemoine, in Børgesen, Marine Algae of the Danish West Indies, II, 1920, p. 170, fig. 165.

Frond forming whitish fragile crusts on various algae, 2 to 5 mm. in diameter or more. Vegetative cells subrectangular in surface view, 8 to 14  $\mu$  broad and 16 to 28  $\mu$  long. Colorless swollen cells or "heterocysts" present, 1.5 to 2.0 or more times larger than the vegetative ones. Sporangial conceptacles hemispherical or conical, scattered or somewhat crowded, 140 to 250  $\mu$  in diameter, with tetrasporangia 30 to 50  $\mu$  in diameter and 50 to 90  $\mu$  long. Cystocarpic conceptacles similar in size and shape, but the spermatangial ones much smaller, being only about 60 to 80  $\mu$  in diameter.

*Habitat.* — Epiphytic on *Laurencia* from Cape d'Aguilar, Hong Kong I., in March (Tseng 2691a); on *Caulerpa*, washed ashore, Clearwater Bay, Port Shelter, in February (Taam A33d).

*Distribution.* — Probably cosmopolitan.

#### 6. *Fosliella Lejolisii* (Rosan.) Howe

Howe, Bahama Algae, 1920, p. 588; Taylor, Marine Algae of Northeastern . . . North America, 1937, p. 270, pl. 36, figs. 6-8.

*Melobesia Lejolisii* Rosanoff, Recherches, 1866, p. 62, pl. 1, figs. 1-18; Hauck, Meeresalgen, 1885, p. 264, fig. 108.

Frond forming delicate, dull pink or pale reddish thin crust up to about 2 mm. broad. Vegetative cells about 6 to 10  $\mu$  broad in surface view, and somewhat longer. Heterocysts absent. Conceptacles and sporangia similar to those of the preceding species in shape and size.

*Habitat.* — Epiphytic on *Herposiphonia*, intermingled with *Falkenbergia*, from Clearwater Bay, Port Shelter, in May (Tseng 2803b).

*Distribution.* — Cherbourg, France (type locality); probably cosmopolitan.

7. *Gymnogongrus divaricatus* Holm.

Holmes, New Marine Algae from Japan, 1895, p. 255, pl. 7, fig. 3 a-b; Okamura, Icones of Japanese Algae, VII, ii. 1933, p. 16, pl. 310, figs. 1-5.

Frond regularly divaricately, dichotomously, flabellately branched, up to 3 cm. high. Branches linear-compressed, about 1 mm. broad. Segments of approximately equal length and breadth throughout, slightly cuneate at the base, bifid at the apices. Proliferation common on the lower branches. Plants rather cartilaginous and purplish red.

*Habitat.* — Tufted on sand-covered rocks and in rock pools in the littoral region in April: Stanley Beach, Hong Kong I. (*Tseng* 283) and Putoi I. (*Tseng* 2742).

*Distribution.* — Province Kii, Shimoda, Misaki, and Province Totomi, Japan.

8. *Gracilaria Blodgettii* Harv.

Harvey, Nereis Boreali-Americana, II, 1853, p. 111; Taylor, Marine Algae of Florida, 1928, p. 151, pl. 23, fig. 9, pl. 33, fig. 6; Weber-van Bosse, Liste des algues du Siboga, IV, 1928, p. 430, fig. 174.

Frond richly branched, arising from a discoid holdfast up to 10 cm. high. Branching lateral, very irregular, with longer and shorter branches intermingled. Branches about 1 mm. in diameter, abruptly constricted at the base and quickly tapering to fine points at the apices. Cystocarps numerous, conical, scattered over the frond. Plants firmly succulent and yellowish to light brownish red.

*Habitat.* — On rocks in the lower littoral region, Clearwater Bay, Port Shelter, in May (*Tseng* 2802).

*Distribution.* — Key West, Florida (type locality) and the West Indies; Kei I.; Java.

9. *Wurdemannia miniata* (Drap.) Feldm. et Hamel

Feldmann et Hamel, Observations sur quelques Gelidiacées, 1934, p. 17, figs. 9-11; *idem*, Floridées de France, VII, 1936, p. 260, figs. 34-36.

*Gigartina miniata* (Drap.) Lamouroux, Essai, 1813, p. 137 (*nomen nudum*).

*Fucus miniatus* Draparnaud, Ined., De Candolle, Flore française, V, 1815, p. 6.

*Gelidium miniatum* Kützting, Species algarum, 1849, p. 767; *idem*, Tabulae phycologicae, XVIII, 1868, pl. 58, figs. c-h.

*Wurdemannia setacea* Harvey, Nereis Boreali-Americana, II, 1853, p. 246; Kützting, Tabulae phycologicae, 1869, pl. 26; Bergesen, Marine Algae of

the Danish West Indies, II, 1920, p. 368, figs. 360-361; *idem*, Marine Algae from the Canary Islands, II, ii, 1929, p. 77, fig. 28; Taylor, Marine Algae of Florida, 1928, p. 145, pl. 20, figs. 9-10.

*Distribution*. — Vicinity of Montpellier (type locality), Port-Vendres, Algeria, both of the Mediterranean; Florida and the West Indies.

Var. *planicaulis* Taylor, Marine Algae from Haiti, 1943, p. 158.

Frond with a rhizomatous part, from which arise the erect branches to about 7 cm. high. The branching rather sparse, irregularly lateral and subpinnate. Basal filaments cylindrical. Branches of the erect portions distinctly compressed, reaching a breadth of 0.7 mm. Materials all sterile.

*Habitat*. — On sand-covered rocks in the littoral region, Big Wave Bay, Hong Kong I., in June (Tseng 2854).

The Hong Kong plant is in exact accord with the Haitian form recently described.

#### 10. *Ceramium byssoideum* Harv.

Harvey, Nereis Boreali-Americana, II, 1853, p. 218; Howe, Bermuda Algae, 1918, p. 531; Weber-van Bosse, Liste des algues du Siboga, III, 1923, p. 330.

*C. transversale* Collins & Hervey, Algae of Bermuda, 1917, p. 145, pl. 5, figs. 29-31; Børgesen, Marine Algae of the Danish West Indies, II, 1920, p. 243, fig. 233; *idem*, Marine Algae . . . from Beata Island, 1924, p. 27, fig. 9; *idem*, South Indian Marine Algal Flora, III, 1938, p. 229.

Frond minute, epiphytic on various plants. Creeping filaments 45 to 75  $\mu$  in diameter, with cells generally about two to five times the diameter in length, cylindrical or slightly constricted at the nodes. Erect branches with somewhat shorter cells. The filament repeatedly dichotomously branched. Cortical cells limited to the nodes, characteristically transversely placed, with their long axes perpendicular to that of the filament. Tetrasporangia about 60  $\mu$  in diameter, borne singly, rarely in twos, at a node, nearly free from the cortication.

*Habitat*. — On Laurencia in March (Taam A72a) and on Gelidium in July (Tseng 2857c), both from Shek-O, Hong Kong I.

*Distribution*. — Key West, Florida (type locality); widely distributed in warmer temperate and tropical seas.

#### 11. *Ceramium crassum* Okam.

Okamura, Icones of Japanese Algae, VI, iv, 1930, p. 26, pl. 269.

Frond epiphytic on larger algae. Filament divaricately dichotomously branched, up to 8 cm. high, 0.7 mm. in diameter below,

gradually attenuated to about  $90\ \mu$  in diameter above. Apices lightly or strongly forcipate. Cortication occurring evenly throughout, rather thick, composed of four to five layers of cells, which gradually become smaller outward. Segments sometimes abundantly furnished with secund or irregularly disposed, short proliferous branchlets, often quite naked and devoid of such proliferations. Cystocarps pedicellate and involucrate, fertile branchlets proliferating from the segments secundly or irregularly. Tetrasporangia about  $60\ \mu$  in diameter, immersed in the cortex and scattered over the surfaces of the branchlets.

*Habitat.* — On Cystophyllum, washed ashore, Shek-O, in December (*Tseng 2595*) and January (*Taam A25*).

*Distribution.* — Tyoshi, Enoshima, Japan (type locality).

This is the southern substitute for the northern *Ceramium rubrum*, with which it is closely related; the chief difference lies in its having a much thicker cortex.

## 12. *Caloglossa ogasawaraensis* Okam.

(Plate I, Figure 7)

Okamura, Algae from Ogasawara-jima, 1897, p. 13, figs. A-D; *idem*, Icones of Japanese Algae, I, viii, 1908, p. 183, pl. 37, figs. 1-11; Post, Notizen, 1936, p. 60.

*C. sanzibariensis* Goebel, Süßwasserfloridee aus Ostafrika, 1898, p. 65, figs. 1-6.

*C. bombayensis* Bergesen, Some Indian Rhodophyceae, III, 1933, p. 127, figs. 10-12; Post, *op. cit.*, p. 61.

Frond repent, bilaterally branched, with percurrently main axis and elongated linear-lanceolate internodes up to about  $260\ \mu$  broad, and as much as fourteen times as long. Branches generally better developed on one side than on the other. Blades with about six rows of cells on each side of the midrib. Tetrasporangia  $45$  to  $60\ \mu$  in diameter, forming two elongated rows on both sides of the midrib.

*Habitat.* — On muddy rocks in a sheltered tidal ditch in the littoral region, Shatin, Tide Cove, in April (*Tseng 2727*) and July (*Taam A145*).

*Distribution.* — Ogasawara (Bonin) Islands (type locality); widely distributed from Japan in the east to East Africa in the west.

The Hong Kong specimens certainly resemble *C. bombayensis* Berg. much more than do the Japanese type. Though Post, *op. cit.*, differentiates these two species on the basis of the relative development of the lateral branches on both sides, she does not take into

consideration the great variability of plants of this genus in different environmental conditions. The writer was at first tempted to separate the two forms on the same basis. Having studied authentic species of the Japanese as well as the Bombay plants, he cannot help believing that there is a whole series of intergrading forms between *C. ogasawaraensis* on the one hand and *C. bombayensis* Børg. on the other.

*C. zanzibariensis* Børg. is regarded by both Okamura, *op. cit.*, and Post, *op. cit.*, as synonymous with the earlier published Japanese species. Its blade has a breadth of 250 to 400  $\mu$  and eight rows of cells on both sides of the midrib. Since the Hong Kong plant has its blade about 200 to 250  $\mu$  broad and six rows of cells on both sides of the midrib, it apparently stands between the East African and the Bombay algae. Without a certain line of demarcation between the two presumably independent species, it seems to the writer more natural to refer the various described "species" of this *Caloglossa ogasawaraensis-zanzibariensis-bombayensis* complex to a single specific entity. He sent one of these specimens to Dr. Børgesen, who made the following remark in his letter:

"Taam A145 seems to be nearest to *C. bombayensis*; the broadest thallus I have measured was 260  $\mu$ , thus somewhat thicker than the type specimens from Bombay. This plant is also *einseitig*-branched, agreeing with my figure. But I have no doubt that these plants and *Cal. ogasawaraensis* are connected by intermediate forms."

It is evident that Dr. Børgesen himself also questions the advisability of separating the two extreme forms of this complex, namely, *C. ogasawaraensis* and *C. bombayensis*.

### 13. *Chondria hapteroclada*, sp. nov.

(Plate II, Figures 1-4)

Frons fulvipurpurea, filiformis, intricata, repens, pulvinata; pulvinis valde extensis, ca. 1.5 cm. altis; filamentis teretibus, usque ad 0.72 mm. altis, pinnate decompositis, per cladohaptera rhizoidea elongata inter se adhaerentibus et ad rupes adfixis; ramis alternis vel suboppositis, apice interdum arcuatis; ramulis ultimis distichis vel tristichis, clavatis, basi leviter constrictis; apicibus ramorum ramulorumque truncatis, punctis vegetativis in foveam crateriformem immersis; in sectione transversali: cellulis epidermalibus late rect-

angularibus, 20–24  $\mu$  altis, 24–30  $\mu$  latis, cellulis pericentralibus 5, cortice crasso, circiter 5-strato; tetrasporangiis usque ad 90  $\mu$  diam., in ramulis ultimis simplicibus aut ramosis ortis. Cystocarpia et acervuli spermatangiales ignota. Species Chondriae repenti Børg. proxima videtur.

*Specimen typicum.* — Tseng 2783 (in herbario auctoris) ad rupes arenosas zonae superioris litoralis in aqua tranquilla, prope Saiwan, Hong Kong I., 14 Mai, 1940.

Fronde forming very extensive pulvinate patches to about 1.5 cm. high, filiform and repeatedly, rather abundantly pinnately branched. Filaments terete, to 0.72 mm. in diameter, mostly decumbent and intricately intertwined, forming haptera here and there, by which the neighboring segments adhere to one another and with which the plant attaches itself to the substratum (Pl. II, Fig. 1). Haptera modified from ventral branchlets, unicellular rhizoids about 30  $\mu$  in diameter generally issuing at their tips (Pl. II, Fig. 2), sometimes remaining stunted and undeveloped when two segments are too close to each other. Branches virgate, alternate or subopposite, sometimes with arcuate tips. Ultimate branchlets clavate, slightly constricted at the base, and arranged in three, sometimes two, ranks, with the ventral ones usually converted into the haptera. Apices of the branches and branchlets all truncate, with the growing point sunken in a crater-like pit. Epidermal cells in surface view hexagonal or somewhat rounded. In transverse section epidermal cells broadly rectangular, 20 to 24  $\mu$  high and 24 to 30  $\mu$  broad; pericentral cells five, surrounded by a rather thick cortex, generally four- to five-layered, with parenchymatous cells similar to them in shape and size (Pl. II, Fig. 4). The central strand thus rather obscured, especially in the older segments. Tetrasporangia about 90  $\mu$  in diameter, scattered rather evenly in the ultimate segments, which are either simple or branched (Pl. II, Fig. 3). Cystocarps and spermatangial clusters not found.

*Habitat.* — Forming extensive pulvinate patches on sandy loam and muddy rocks in the upper littoral region among mangroves, Shatin, Tide Cove, in April (Tseng 2728), and Saiwan, Hong Kong I., in May (Tseng 2793, TYPE).

The present species, a member of the subgenus *Coelochondria*, is most closely related to *C. repens* Børg. from Easter Island. The latter species is, however, a very small epiphyte on other algae; it is

only about 1 to 2 mm. high, with filaments 0.2 to 0.4 mm. broad, sparsely and rather irregularly branched, and with obovate branchlets.

#### 14. *Chondria lancifolia* Okam.

(Plate II, Figures 5-7)

Okamura, *Icones of Japanese Algae*, VII, v, 1934, p. 43, pl. 323, figs. 1-10.

Fronde small, slender, epiphytic, bright red, to about 1 cm. high. Basal parts prostrate, attaching to the host by means of short, stout bundles of rhizoidal fibers. Erect parts once or twice alternately pinnately branched with flattened, leaflike blades about 0.17 mm. thick and up to 0.65 mm. broad, deeply constricted at the base and tapering above into fine points (Pl. II, Fig. 5). Apex convex and acute, with a large protruding apical cell. Branches sometimes firmly attaching to one another by emitting adhesive rhizoidal fibers (Pl. II, Fig. 5). Trichoblasts dichotomously branched and developed alternately near the tips (Pl. II, Fig. 6). Transverse section of the leaflike branch showing five pericentral cells surrounding a large central cell, and many large medullary cells bounded by a more or less differentiated layer of epidermal cells about 12 to 18  $\mu$  broad at the periphery (Pl. II, Fig. 7). Lenticular thickenings at the walls of the medullary cells present, especially in older portions, and in some places clearly visible through the cortex in surface view. Materials all sterile.

*Habitat*. — On *Caulerpa*, drifted ashore, Clearwater Bay, Port Shelter, in February (*Taam A33b*).

*Distribution*. — Warmer parts of Japan on the coasts of both the Pacific Ocean and the Japan Sea.

This species is a very characteristic one among the *Platychondria* and is easily recognized by its epiphytic habit, its sparingly and alternately pinnate frond, its irregularly placed bundles of rhizoidal fibers, its branches deeply constricted at the base and tapering above to sharply acute apices, and its lenticular thickenings in the medullary cells. The Hong Kong plants are sterile and much smaller in all respects than the typical Japanese ones. Nevertheless, the writer feels quite convinced that his plant represents young stages of the same species. This species is among the rare components of the Chinese marine flora.

15. *Lophosiphonia subadunca* (Kütz.) Falk.

Falkenberg, Die Rhodomelaceen, 1901, p. 496; Howe, Bahama Algae, 1920, p. 274; Børgesen, Marine Algae from the Iranian Gulf, 1939, p. 132.

*Polysiphonia subadunca* Kützling, Phycologia generalis, 1843, p. 418; *idem*, Tabulae phycologicae, XIII, 1863, pl. 32, figs. a-c; J. G. Agardh, Species . . . algarum, III, iii, 1863, p. 1064; Hauck, Meeresalgen, 1885, p. 235.

*Hutchinsia obscura* C. A. Agardh, Species algarum, II, 1828, p. 108 (fide Howe, *op. cit.*).

*Polysiphonia barbatula* Kützling, Phycologia generalis, 1843, p. 417; *idem*, Tabulae phycologicae, XIII, pl. 33, figs. a-d.

*Polysiphonia pygmaea* Kützling, Phycologia germanica, 1843, p. 313; *idem*, Tabulae phycologicae, XIII, 1863, pl. 29, figs. a-d.

Frond with long shoots and main filaments horizontally creeping, attaching by means of stout unicellular rhizoids about 30  $\mu$  in diameter, which are separated from the mother pericentral cells by a cross wall or, in some, by a small cell. Dwarf shoots erect, dorsally issued. Long shoots lateral, occurring at intervals of two to seven segments. Branches generally all simple, strongly ventrally curved when young, reaching a height of 5 mm. and having as many as fifty segments, more commonly thirty to forty. Trichoblasts very well developed on the upper parts of the dwarf shoots, each with a large basal cell of about 35  $\mu$  in diameter and three to five times subdichotomously branched. Main filaments and long shoots about 90 to 120  $\mu$  in diameter and the dwarf shoots, 60 to 90  $\mu$  in diameter, tapering to about 30  $\mu$  in diameter at the distal ends. Segments about as long as broad throughout, becoming very much shortened near the tips. Tetrasporangia about 60  $\mu$  in diameter, occurring in short spiral series of six to nine in the upper parts of the dwarf shoots.

*Habitat.* — Forming intricate patches on muddy loam among mangroves in the upper littoral region, Taipohui, Tolo Harbour, in April (*Tseng 2733*); on bark of mangroves near the upper littoral region, Shatin, Tide Cove, in April (*Tseng 2754*); on mud-covered rocks among mangroves in the littoral region, Shatin, Tide Cove, in July (*Taam A144*); intermingled with *Caloglossa* and *Bostrychia*, on mud-covered barks of mangrove trees near the upper littoral region, Aberdeen, Hong Kong I., in July (*Tseng 2575b*).

*Distribution.* — Corsica, Mediterranean Sea (type locality) and southern Europe; Bahama Is.; Iranian Gulf.

The identification of the Hong Kong plant with the Corsican alga is made with some reservation. The type specimen, according



to Falkenberg, *op. cit.*, has six pericentral cells. In the works cited J. G. Agardh, Hauck, and Børgesen all give similar reports. Howe, *op. cit.*, however, credits this species with a variable number of pericentral cells varying from six to ten. In the Hong Kong specimens the writer has found the number of these cells to vary from six to eight. Since his plant agrees in all other respects with the others mentioned above, he has to share the view of Howe, and, for the time being at least, to be content with the determination given. It is to be noted that Howe's plant was found on surf-beaten rocks, whereas the writer's were from a very sheltered mangrove swamp. The Bahama plants are more yellowish and smaller than those from Hong Kong. Otherwise they agree perfectly well with each other. The Chinese plants are also somewhat larger than the Iranian alga, which Børgesen reports to be only 90  $\mu$  in diameter.

#### SUMMARY

Fifteen species of marine algae are added to the floristic list of Hong Kong. All these are recorded for the first time from Chinese waters. One species is here described as new, namely, *Chondria hapteroclada*, which belongs to the subgenus *Coelochondria*, and is closely related to *C. repens* Børg. from Easter Island.

The writer wishes to thank Professor William Randolph Taylor, of the University of Michigan, for his advice in this study.

UNIVERSITY OF MICHIGAN

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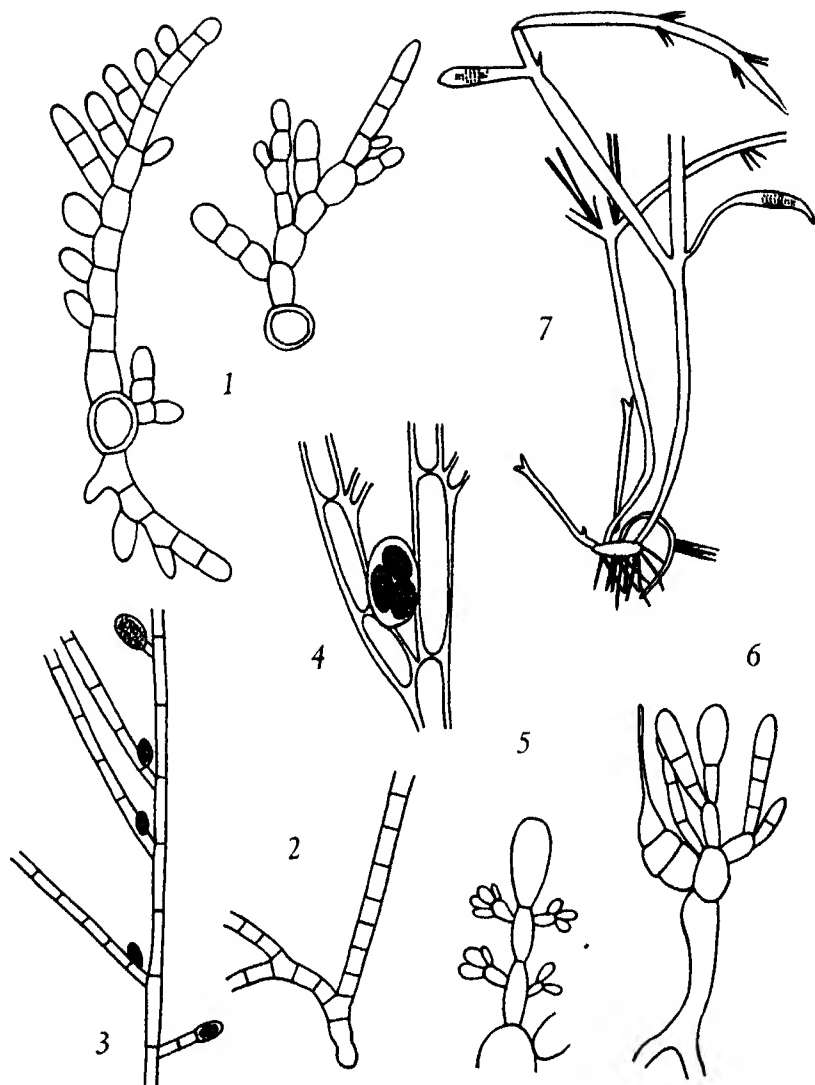
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## EXPLANATION OF PLATE I

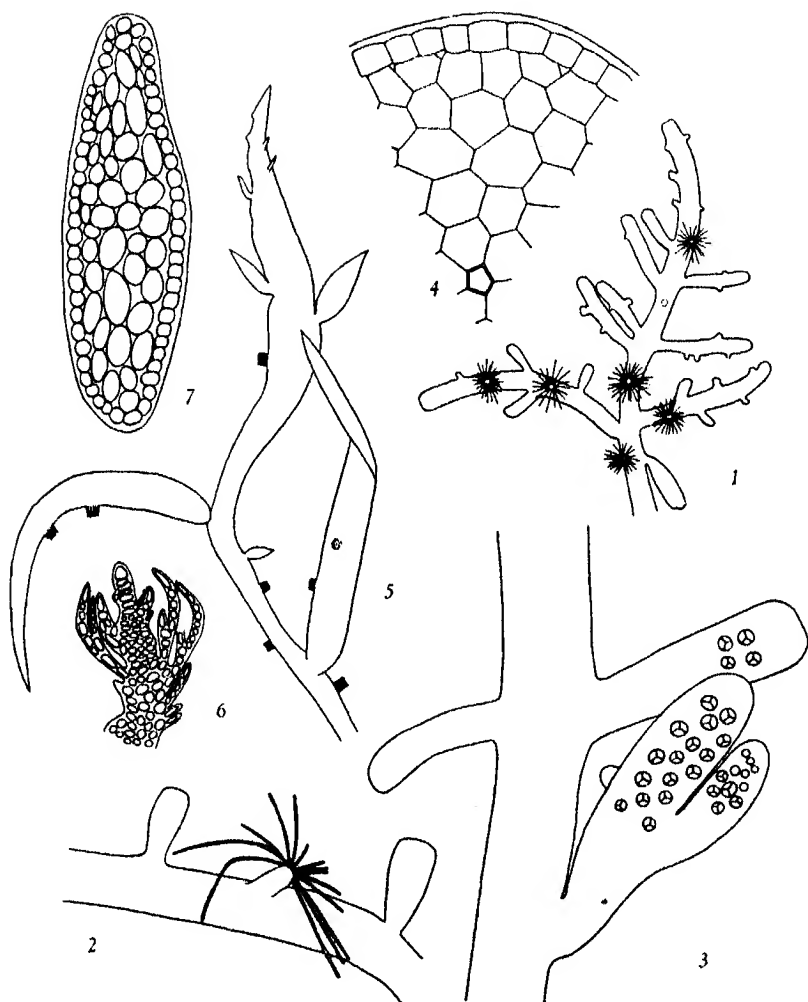
- FIG. 1. *Achrochaetium arcuatum* (Drew), comb. nov. Two young plants, showing basal cells and branching.  $\times 553$
- FIG. 2. *A. robustum* Børg. Basal part of a plant, showing a basal cell.  $\times 188$
- FIG. 3. *A. robustum* Børg. Part of a plant, showing five monosporangia.  $\times 188$
- FIG. 4. *A. robustum* Børg. Part of a branch bearing a tetrasporangium.  $\times 553$
- FIG. 5. *Dermoneia gracilis* (v. Mart.) Schmitz. Part of a cortical filament bearing spermatangia.  $\times 553$
- FIG. 6. *D. gracilis* (v. Mart.) Schmitz. Cortical filament bearing a carpogonial branch.  $\times 307$
- FIG. 7. *Caloglossa ogasawaraensis* Okam. Habit sketch of a tetrasporiferous plant.  $\times 9$



Marine algae from Hong Kong

## EXPLANATION OF PLATE II

- FIG. 1. *Chondria hapteroclada*, sp. nov. Habit sketch showing the branching and the rhizoids.  $\times 4$
- FIG. 2. *C. hapteroclada*, sp. nov. Lateral view of a filament showing two branchlets and a third one modified to become a hapteron with terminal rhizoids.  $\times 17$
- FIG. 3. *C. hapteroclada*, sp. nov. Part of a branch with tetrasporangia.  $\times 17$
- FIG. 4. *C. hapteroclada*, sp. nov. Transverse section of a branchlet.  $\times 158$
- FIG. 5. *C. lancifolia* Okam. Habit sketch showing the branching and the rhizoids.  $\times 12$
- FIG. 6. *C. lancifolia* Okam. Apex of a branch.  $\times 203$
- FIG. 7. *C. lancifolia* Okam. Transverse section of a branch.  $\times 100$



Marine algae from Hong Kong





# FORESTRY



## SOME RESUPINATE POLYPORES FROM THE REGION OF THE GREAT LAKES. XVI \*

DOW V. BAXTER

THERE are many classical papers and other reports that deal with the decay of wood in culture by various fungi. No systematic attempt, however, has heretofore been made to compare the reactions of a large group of isolates on similar substratum of many different species of resupinate polypores collected from widely separated localities of the continent and found on a great variety of woods. I have based this paper on a large number of species and races obtained in culture from the Michigan collections. Each isolate was placed on red-gum and white-pine blocks regardless of the kind of wood originally attacked by the organism. The macroscopic effects of these fungi upon these test woods have been noted and, furthermore, records of the mycelial growth on malt extract in petri-dish cultures have been secured.

Distinctions that can be made between many species and races of the white resupinate polypores in such cultures have been recorded in key form in Paper XV (29 [1943]: 85-109) of this series. The limitations of methods that may be used to distinguish the resupinate polypores are likewise discussed in that account. The key there presented is continued in the present paper, which deals with the light- and dark-colored species of the group.

As in the previous paper, all growth measurements are averages

\* Throughout the work on these monographs I have been indebted to many individuals and institutions for suggestions, help, and privileges. My appreciation is expressed particularly to the men who accompanied me on my ten expeditions to Alaska, the Yukon Territory, and the Northwest Territories. They aided in the collection and care of specimens, sometimes under rather difficult circumstances. I am under obligation to Professors T. G. Halle and Gunnar Samuelson, of Naturhistoriska Riksmuseet in Stockholm, with whom I have had the pleasure of being associated. Thanks are due to several American institutions and scholars, also: to the authorities at the New York Botanical Garden; to Dr. W. H. Long, Albuquerque, New Mexico; to the staff of the Division of Pathological and Mycological Collections of the United States Department of Agriculture; and to Professor H. H. Bartlett and Mr. Reed W. Varner, of the University of Michigan.

of the two longest radii emanating from the inoculum, which was not measured.

The color terms enclosed in quotation marks are those of R. Ridgway, *Color Standards and Color Nomenclature* (1912).

#### KEY TO THE PRINCIPAL LIGHT-COLORED RESUPINATE POLYPORES IN CULTURE

The light-colored mycelium in both petri-dish tests and one-year-old wood-block cultures characterizes the resupinate polypores listed in this key. In general, the key does not include those plants which have "avellaneous" or brown mycelium. Certain species with fruiting bodies that are brown or of a dark color are grouped here, however, since they either exhibit a light-colored mycelium for a number of weeks or show light-colored as well as dark-colored mycelium in cultures. *Lenzites trabea*, for example, is often salmon, i.e. "capucine buff," in young cultures. Likewise, certain white resupinate polypores, such as *Poria unita*, are included in this key since mycelial colors change from white to yellow, depending upon environmental conditions, especially the degree of darkness. *Poria cocos* is actually a white plant, but the mycelium may be "cinnamon" or "Mikado brown" as well as white. It is placed in the light-colored group. No attempt has been made to revise generic concepts in this key. Generic names that are usually applied to the species are employed throughout.

#### KEY TO LIGHT-COLORED RESUPINATES

1. Cultures forming thick sheets of mycelium that develop so luxuriantly that the fungus extends between the lid and the dish or grows up over the lid of the petri dish for several millimeters at 30° C. .... 2
1. Cultures not forming such thick sheets or showing such mycelial growth within two weeks that the fungus grows out between the lid and the dish or up over the lid of the petri dish at 30° C. .... 5
2. Mycelium distinctly pink, i.e. "pale vinaceous fawn," at 25° C.  
*Poria rufa*<sup>1</sup> on *Picea glauca*, Fort Wrigley,  
 Northwest Territories (mycelium fills  
 petri dish at 35° C.). Pl. I, Fig. 1

<sup>1</sup> These three isolates cannot be distinguished in one-year-old red-gum block cultures. This might well indicate that the ponderosa-pine fungus and the isolate from *Taxodium distichum* belong to *Poria rufa*. Colors for each of the three fungi in one-year-old flasks are whitish to "Sabal brown," and the brown is conspicuous. Both petri-dish and flask cultures seem to indicate that these isolates may be of the same species.

Unknown *Poria* on *Pinus ponderosa*, locality not specified (mycelium fills petri dish at 35° C.)

Unknown *Poria* on *Taxodium distichum*, railroad ties, Georgia. (Mycelium occasionally fills petri dish at 35° C., but average of tests is 20 mm. Variation in rate of growth not significant, and mycelium in petri dishes and in flasks appears to be almost identical with the other fungi in this section of the key.)

2. Mycelium not pink but white, yellowish cream, or salmon at 25° C. . . . . 3
3. Mycelium white, "avellaneous," "vinaceous buff," or yellowish at 25° C. . . . 4
3. Mycelium cream or salmon, i.e. "capucine buff," at 25° C.

*Lenzites trabea* ex U. S. Division of Forest Pathology, Forest Products Laboratory, Madison. Pl. I, Fig. 2

4. Mycelium white or yellowish and filling petri dish at 25° C. in two-week-old cultures

*Poria unita* on *Quercus* sp., Michigan (pore formation evident). Pl. I, Fig. 3

*Poria unita pulchella*, Selkirk, Yukon Territory (pore formation evident). Pl. I, Fig. 4

*Poria unita pulchella* U. 26 on *Populus balsamifera*, Burnt Island, Great Slave Lake, Northwest Territories (pore formation evident). Pl. II, Fig. 1

4. Mycelium white or "avellaneous" or "vinaceous buff" at 25° C. and usually not filling dish (i.e. showing growth of approximately 30 or 35 mm. at 25° C.)

*Poria nigra* ex U. S. Division of Forest Pathology, Washington, 71073. Pl. IV, Fig. 3

5. Culture exhibiting more than 15 mm. growth at 30° C. and usually filling the petri dish at this temperature . . . . . 6

5. Culture exhibiting not more than 15 mm. growth at 30° C.

*Polyporus aboluteus* on *Picea sitchensis*, Juneau, Alaska. Pl. II, Fig. 2

6. Culture filling petri dish in two-week-old test at 35° C., but not including those that are arachnoid or water-soaked in appearance, mycelium white or yellow, not pink or some other color

*Poria unita* on *Quercus* sp., Michigan (pore formation evident). Pl. I, Fig. 3

*Poria unita pulchella*, Selkirk, Yukon Territory (pore formation evident). Pl. I, Fig. 4

*Poria unita pulchella* U. 26 on *Populus balsamifera*, Burnt Island, Great Slave Lake, Northwest Territories (pore formation evident). Pl. II, Fig. 1

6. Culture not filling petri dish in two-week-old test at 35° C., or, if filling dish, arachnoid or water-soaked in appearance, mycelium white, yellow, pink, or some other color ..... 7
7. Mycelium exhibiting a growth of more than 15 mm. at 35° C. .... 8
7. Mycelium exhibiting a growth of less than 15 mm. at 35° C. .... 9
8. Mycelium on agar surface distinctly pink or orange at 35° C.; not appressed

*Poria spissa* on hardwood, Michigan (pore formation evident). Pl. II, Fig. 3

*Poria semitincta* on *Quercus marilandica*, North Carolina (fungus variable in culture, i.e. sometimes not distinctly pink and at times appressed, but occasionally falling in this section of key because of growth rates and temperature relations. Readily distinguished from *Poria spissa* by lack of orange color; see 13). Pl. II, Fig. 4

*Fomes subroseus* on *Larix laricina*, Michigan. (Fungus variable in culture at this temperature, and sometimes it is not distinctly pink within the time limit of the test. It can readily be separated from cultures of *Poria spissa* and *Poria semitincta* by the nodular type of pore formation produced on wood blocks.) Pl. IV, Fig. 1

8. Mycelium on agar surface not pink;\* appressed, especially about inoculum, or arachnoid at 35° C. .... 14
9. Culture appearing water-soaked at 25° C., i.e. growth thin so that mycelium does not mask agar from view; somewhat arachnoid ..... 13
9. Culture not appearing water-soaked but forming a somewhat thicker growth at 25° C., so that the mycelium appears more cottony than arachnoid ..... 10
10. Mycelium throughout culture white to "cinnamon buff" at 25° C. and not exhibiting a uniform type of growth, i.e. mycelium forming a definitely cottony ring of "cinnamon buff" mycelium about the inoculum

*Poria mulans tenuis* on *Castanea dentata*, Georgia. Pl. III, Fig. 1

10. Mycelium exhibiting a more or less uniform color throughout culture and also a uniform type of growth at 25° C. .... 11
11. Mycelium in the form of thick strands that radiate from the inoculum at 25° C.

*Poria incrassata* ex U. S. Division of Forest Pathology, Forest Products Laboratory, Madison. Pl. III, Fig. 2

\* *F. subroseus* is pinkish in older cultures and especially on wood blocks. The color is not always evident in two-week-old cultures at this temperature.

11. Mycelium not in the form of thick strands that radiate from the inoculum at 25° C. . . . . 12
12. Mycelium white to "avellaneous," not pink at 25° C. . . . . 15
12. Mycelium showing pink at 25° C. . . . . 16
13. Culture exhibiting growth on agar surface at 35° C.
  - A. Mycelium in one-year-old red-gum block cultures flocculent, somewhat nodulose, growth so luxuriant that the edges and shape of the blocks are generally hidden
 

*Poria spissa* on hardwood, Michigan (fungus readily distinguished from *Poria semitincta*, particularly in petri-dish or younger flask cultures, by the bright pink and orange mycelium of *Poria spissa*). Pl. II, Fig. 3
  - A. Mycelium in one-year-old red-gum block cultures more arachnoid than flocculent, not nodulose, edges and shape of wood blocks distinct
 

*Poria semitincta* U. 23 on *Quercus marilandica*, North Carolina (colors of mycelium not bright as in *Poria spissa* and definitely not orange). Pl. II, Fig. 4
13. Culture not exhibiting growth on the agar surface at 35° C.
 

*Poria eupora* on *Quercus borealis maxima*, Michigan. Pl. III, Fig. 3
14. Mycelium yellowish, especially about the inoculum, at 35° C.
 

*Poria luteofibrata* on *Pinus rigida serotina*, Florida. Pl. III, Fig. 4
14. Mycelium not yellowish
  - A. One-year-old red-gum block cultures pinkish; nodular type of fruiting structures present
 

*Fomes subroseus* on *Larix laricina*, Michigan. Pl. IV, Fig. 1
  - A. One-year-old red-gum block cultures brown as well as white; nodular type of fruiting structures not present
 

*Poria cocos* ex U. S. Division of Forest Pathology, Washington, 72199, from *sclerotium*, Florida (no pore formation within two weeks, but pores form in older test cultures. Mycelium whitish to "avellaneous," cottony and not chamois-like as in isolates of *Poria unita*)

*Poria cocos* ex U. S. Division of Forest Pathology, Washington, on ash, Vermont, det. Davidson (no pore formation within two weeks; mycelium whitish to "avellaneous," cottony and not chamois-like as in isolates of *Poria unita*)
15. Mycelium granular, i.e. mealy in appearance, at 25° C.
 

*Poria purpurea* on *Pinus contorta*, Jasper National Park, Alberta. Pl. IV, Fig. 2



## 15. Mycelium not granular in appearance at 25° C.

- A. Mycelium in one-year-old red-gum block cultures nodular, fruit formation often appearing as pink nodular structures; culture more pinkish than brown

*Fomes subroseus* on *Larix laricina*, Michigan. Pl. IV, Fig. 1

- A. Mycelium in one-year-old red-gum block cultures not distinctly nodular, fruit formation (if present) not in the form of pink nodular structures; culture more chocolate brown than pink

*Poria nigra* ex U. S. Division of Forest Pathology, Washington, 71078. Pl. IV, Fig. 3

*Poria nigra* ex U. S. Division of Forest Pathology, Washington, 71099, on *Quercus velutina*, Illinois. Pl. IV, Fig. 4

An isolate of *Poria nigra*, 71118, is not included in this group since this fungus lacks the color which distinguishes the group.

## 16. Mycelium granular, i.e. mealy, at 25° C. in two-week-old tests

*Poria purpurea* on *Pinus contorta*, Jasper National Park, Alberta. Pl. IV, Fig. 2

## 16. Mycelium not granular at 25° C. in two-week-old tests

- A. One-year-old red-gum block cultures exhibiting fructifications, often in the form of pink nodules; mycelium not masking the block edges or shape of the test pieces from view

*Fomes subroseus* on *Larix laricina*, Michigan. Pl. IV, Fig. 1

- A. One-year-old red-gum block cultures not exhibiting conspicuous nodules that usually produce pores; mycelium growing luxuriantly over the blocks, so that the shape of the test pieces is masked from view

*Poria spissa* on hardwood, Michigan (fungus readily distinguished from *Fomes subrosea*, particularly in petri-dish or younger flask cultures, by the bright pink and orange mycelium of *Poria spissa*). Pl. II, Fig. 3

# KEY TO THE PRINCIPAL BROWN RESUPINATE POLYPORES IN CULTURE

The brown-colored mycelium in both petri-dish tests and one-year-old wood-block cultures characterizes the resupinate polypores listed in this key. The group includes both the woody *Fomes*-like forms and the annuals. No attempt has been made to revise generic concepts, and the names presented are those usually applied to the plants. Several of the species have light-colored or even white

mycelium at first. White plants such as isolates of *Poria cocos* often have brown mycelium in culture. These are not included in the key, since they have been placed in the light-colored or white groups.

## KEY TO BROWN RESUPINATES

1. Mycelium filling petri dishes in two-week-old tests or cultures exhibiting a growth of at least 25 mm., and usually more luxuriant at 35° C. .... 2
1. Mycelium showing a growth of 25 mm. or less in two-week-old tests at 35° C. .... 7
2. Culture exhibiting a luxuriant growth at 35° C., i.e. mycelium growing up and over the sides and cover of the petri dish in two-week-old tests; dark yellow brown, i.e. "yellow ocher," often with dark red brown, i.e. "Rood brown," areas much in evidence at 25° C. in two-week-old cultures; but the red brown later turning to dark brown, i.e. "Saccardo's umber," and not showing red at all. Red not characteristic or not found at all in wood-block cultures or in old petri-dish tests (the most rapidly growing resupinate at 35° C. of all isolates of the brown group)  
*Fomitiporia dryophila*, Race II, on *Carpinus*, Louisiana. Pl. V, Fig. 2
2. Mycelium exhibiting excellent growth at 35° C., but not developing fast enough within a two-week period to cover the interior sides of the dish and lid; mycelium not dark yellow brown, i.e. often more whitish or "avellaneous" mycelium present, "chamois" to "clay color" and never exhibiting red brown ..... 3
3. Culture exhibiting black or dark line formation on the mycelium in two-week-old tests and showing a broad (approximately 1 cm. wide) white border, especially at 25° C. This is in marked contrast to the brown mycelium that surrounds the inoculum.  
*Poria inermis* on *Ilex verticillata*, Michigan.  
(Compare *Poria Andersonii*, which is similar in having black line and agar discoloration, but does not have the distinct white border). See Pl. XXX, Fig. 1 of Paper VIII of this series (22 [1936]: 275-296)
3. Culture not exhibiting definite black line formation on the mycelium in two-week-old tests or, if black lines are present, not showing a wide conspicuous border of white mycelium that surrounds the brown hyphae of the remaining parts of the culture ..... 4
4. Mycelium exhibiting bristle-like spines on the hyphae as seen under the microscope; setal hyphae often present  
*Poria spiculosa* ex U. S. Division of Forest Pathology, Washington, on *Carya* sp.  
(Red-gum block cultures with lines present but not conspicuously so. Basidiospores not produced.) Pl. V, Fig. 3  
*Poria Andersonii* ex U. S. Division of Forest

Pathology, Washington, substratum and locality not specified. (Red-gum block cultures marked with conspicuous lines. Basidiospores sometimes produced.)

4. Mycelium not exhibiting bristle-like spines on the hyphae as seen under the microscope; setal hyphae not present ..... 5
5. Culture exhibiting a uniform type of growth ..... 6
5. Culture not exhibiting a uniform type of growth but radiating instead, or patchy

A. Mycelium in one-year-old wood-block cultures yellow brown and completely enveloping the test blocks; covered with a thick mycelial mat

*Fomitiporia flavomarginata* on *Quercus nigra*, South Carolina. Pl. VI, Fig. 3

A. Mycelium in one-year-old wood-block cultures not yellow brown but whitish to chocolate brown; test blocks thinly covered with mycelium ..... B

B. Cultures fruiting

*Lenzites trabea* ex U. S. Division of Forest Pathology, Forest Products Laboratory, Madison. Pl. I, Fig. 2

B. Cultures not fruiting

*Lenzites saepiararia* on *Picea mariana*, Michigan. Pl. VI, Fig. 4

6. Mycelium more "cinnamon buff" to "clay color" than white at 25° C. in two-week-old tests

*Fomitiporella floridana*, Race II, on *Quercus phellos*, Arkansas (slight wintergreen odor, but not strong as in *Poria laevigata*). Pl. VII, Fig. 2

*Fomitiporia Earleae*, Race I, on *Nyssa biflora*, Florida (very slight wintergreen odor, but not strong enough to be used as a feature of distinction). Pl. VIII, Fig. 1

*Fomitiporia Earleae*, Race II, on *Liquidambar styraciflua*. (No odor. It is clear that odor cannot be used to distinguish the isolates of the group.) Pl. VIII, Fig. 2

6. Mycelium more white than brown at 25° C. in two-week-old tests (growth usually less than 25 mm. in two-week-old cultures)

A. Mycelium in one-year-old wood-block tests forming thick mat over blocks; dark-red areas conspicuous over culture; no fruit formation

*Fomitiporella floridana*, Race I, on *Quercus nigra*, South Carolina. Pl. VII, Fig. 3

A. Mycelium in one-year-old wood-block tests not forming thick mat over blocks; red areas not present in culture; fruit formation conspicuous

*Lenzites trabea* ex U. S. Division of Forest Pathology, Forest Products Laboratory, Madison. Pl. I, Fig. 2

7. Mycelium exhibiting a growth of as much as 15 or 20 mm. at 35° C.; mycelium uniform in color on inoculum and on surface of agar at 35° C.
- A. Mycelium in one-year-old wood-block tests exhibiting conspicuous dark-red areas, sometimes 1 cm. wide, and lines throughout culture  
*Fomitiporella floridana*, Race I, on *Quercus nigra*, South Carolina. Pl. VII, Fig. 3  
*Fomitiporia Earleae*, Race I, on *Nyssa biflora*, Florida. Pl. VIII, Fig. 1
- A. Mycelium in one-year-old wood-block tests without conspicuous broad dark areas. (If lines are present, such lines are fine and narrow, so that red is not a conspicuous color throughout the culture.)  
*Fomitiporia Earleae*, Race I, on *Nyssa biflora*, Florida. Pl. VIII, Fig. 1  
*Fomitiporia Earleae*, Race II, on *Liquidambar styraciflua*, Georgia. Pl. VIII, Fig. 2  
*Polyporus texanus* on *Prosopis julifolia*, Texas. (Fungus differs from the isolates of *Fomitiporia Earleae* by exhibiting arachnoid or "hairy" type of growth on wood blocks, i.e. not so chamois-like or feltlike. Red lines or red areas are never present.)
7. Mycelium not exhibiting more than 10 mm. growth at 35° C. and mostly no growth at this temperature. (If as much as 10 mm. growth is exhibited at 35° C., the new mycelium on the inoculum is of a different color from that on the agar, i.e. brown on the inoculum and white on the agar.) ..... 8
8. Mycelium filling petri dish at 30° C. or exhibiting a growth of as much as 25 mm. at this temperature ..... 9
8. Mycelium not filling petri dish at 30° C. or culture exhibiting less than 20 mm. growth at 30° C. .... 12
9. Mycelium at 30° C. showing at least as much growth as 35 mm., mycelium producing a thick flocculent type of growth, cultures showing a development of 30 mm. or more at 25° C. .... 25
9. Mycelium not filling petri dishes at 30° C., at least with not as much growth as 35 mm. at this temperature, or, if showing approximately 35 mm., culture exhibits an agar discoloration that appears through the mycelium. Growth mostly much less than 30 mm. at 25° C. .... 10
10. Agar discoloration of dark purplish brown, or dark brown evident at 30° C. and showing through the mycelium at this temperature ..... 11
10. Agar not discolored dark purplish brown or dark brown at 30° C., so that red-brown or dark areas show through the mycelium ..... 24
11. Mycelium showing seta-like hyphae as seen under the microscope (not many small spines on the hyphae but the hyphae themselves seta-like).  
 Unknown resupinate X on *Betula kenaica*, Moose Pass, Alaska. Pl. VIII, Fig. 3. (Macroscopically this isolate suggests *Fomes nigricans*, but differs microscopically from that fungus.)

11. Mycelium not showing seta-like hyphae as seen under the microscope  
*Fomes nigricans* U. 42 on *Betula kenaica*,  
 Moose Pass, Alaska  
*Fomes nigricans* on *Betula alba papyrifera*,  
 Minnesota. Pl. VIII, Fig. 4
12. Mycelium exhibiting growth at neither 30° C. nor 25° C. within the two-week test period
  - A. Mycelium in one-year-old wood-block cultures exhibiting black wavy zone lines on wood blocks  
*Fomes nigrolimitatus* 8 F. on *Tsuga heterophylla*, Wrangell, Alaska. Pl. IX, Fig. 1  
*Fomes nigrolimitatus* 7 F. on *Tsuga heterophylla*, Tyee, Alaska
  - A. Mycelium in one-year-old wood-block cultures not exhibiting black line formation on wood  
*Poria ferrea* 9 on *Abies* sp., Oregon. Pl. XII, Fig. 4  
*Poria ferrea* on *Alnus sinuata*, Skagway, Alaska. Pl. XI, Fig. 3  
*Poria ferruginosa* on *Prunus serotina*, Michigan. Pl. XIII, Fig. 3
12. Mycelium exhibiting growth at 30 or 25° C., or at least new growth occurring on inoculum ..... 13
13. Mycelium exhibiting agar discoloration at 30° C. that shows from beneath the mycelium ..... 14
13. Mycelium not exhibiting agar discoloration at 30° C. that can be seen beneath the mycelium ..... 15
14. Agar yellow green as seen from beneath the culture (the yellow green "mignonette green" characteristic of agar in older cultures)  
*Polyporus radiatus* on *Betula kenaica*,  
 Moose Pass, Alaska. Pl. IX, Fig. 2
14. Agar discolored red brown beneath culture  
 Unknown resupinate X on *Betula kenaica*,  
 Moose Pass, Alaska. Pl. VIII, Fig. 3.  
 (Macroscopically this isolate suggests *Fomes nigricans*, but differs microscopically from that fungus.)  
*Polyporus glomeratus* ex Central Experimental Farm, Canada, 11254, on *Acer* sp., Burnet, Quebec. (Mycelium somewhat arachnoid in wood-block cultures and not forming a dense chamois-like mat over the surface of the test piece as in the isolate classed as unknown on *Betula*.)
15. Mycelium exhibiting growth of as much as 15 mm. and usually more at 25° C. .... 18
15. Mycelium not exhibiting as much growth as 15 mm. on agar surface at 25° C. .... 16

16. Mycelial growth hiding outline of inoculum at 30° C., with fluffy growth, but not forming definite growth on surface of agar  
*Pomes Everhartii* on *Quercus borealis maxima*, Michigan. Pl. IX, Fig. 3
16. Mycelial growth not hiding outline of inoculum at 30° C., with fluffy growth, but showing some growth on agar surface ..... 17
17. Mycelium on agar surface cottony at 30° C.  
*Poria Tsugina* on *Abies concolor*, Colorado. Pl. X, Fig. 2
17. Mycelium silky to chamois-like at 30° C. or no growth at all on agar surface
- A. Mycelium in one-year-old wood-block cultures chamois-like; brown; culture definitely not whitish — wavy brown lines often present  
*Poria Tsugina* on *Tsuga heterophylla*, British Columbia. Pl. X, Fig. 3  
*Poria Tsugina* on *Tsuga canadensis*, Michigan. Pl. X, Fig. 4
- A. Mycelium in one-year-old wood-block cultures brown and white, but not totally brown and usually more white than brown; mycelium usually more flocculent than chamois-like, wavy brown lines not present
- Trametes isabellina* 6 W. on *Picea glauca*, Selkirk, Yukon Territory. Pl. XI, Fig. 1  
*Trametes isabellina* 10 W. on *Picea glauca*, Selkirk, Yukon Territory. Pl. XI, Fig. 2  
*Poria ferrea* 9 on *Abies* sp., Oregon  
*Poria ferrea* on *Alnus sinuata* Skagway, Alaska. Pl. XI, Fig. 3  
*Poria ferrea* on *Alnus rubra*, Oregon. Pl. XI, Fig. 4  
*Poria ferrea* on *Acer macrophyllum*, Oregon. Pl. XII, Fig. 1  
*Poria ferrea* on *Corylus* sp., Oregon. Pl. XII, Fig. 2  
*Poria ferrea* ex Central Experimental Farm, Canada, 11253, substratum unknown, Burnet, Quebec  
*Poria ferruginosa* 33 on *Thuja plicata*, Oregon  
*Poria ferruginosa* on *Prunus serotina*, Michigan. Pl. XIII, Fig. 3
18. Culture exhibiting a mat of mycelium of at least a few millimeters (3 or more) on the surface of the agar at 30° C. .... 19
18. Culture not exhibiting a mat of mycelium on the agar at 30° C. .... 22
19. Mycelium exhibiting a cerebriform type of growth at 25° C., or mycelium extending out in fanlike growth from the inoculum  
*Trametes isabellina* 6 W. on *Picea glauca*, Selkirk, Yukon Territory. Pl. XI, Fig. 1  
*Poria ferrugineofusca* on *Pseudotsuga taxifolia*, Oregon. Pl. XIV, Fig. 3

19. Mycelium not exhibiting a cerebriform type of growth at 25° C.; mycelium growing uniformly about inoculum, i.e. not radiating in fanlike type of growth ..... 20
20. Mycelium definitely exhibiting brown colors at 25° C. and as much brown as white or more brown than white, also at 30° C. showing more brown than white ..... 21
20. Mycelium on agar more white than brown at 30 and 25° C.  
*Poria ferrugineofusca* ex Canadian Forest Products Laboratory, F8221A  
*Poria ferrugineofusca* on *Pseudotsuga taxifolia*, Oregon. Pl. XIV, Fig. 1
21. Mycelium red brown, i.e. "Sayal brown" or "avellaneous"
- A. Mycelium in one-year-old wood-block tests uniform in color  
*Poria Weirii* on *Thuja plicata*, locality not specified. Pl. XIV, Fig. 2
- A. Mycelium in one-year-old wood-block tests whitish and brown, i.e. not of the same color throughout the culture  
*Poria ferrugineofusca* on *Tsuga heterophylla*, Skagway, Alaska
21. Mycelium not red brown but "chamois" or "cream buff"
- A. Mycelium in one-year-old red-gum wood-block cultures forming a thin white rhizomorphic growth over test pieces  
*Poria ferruginosa* on *Thuja occidentalis*, Minnesota. Pl. XIII, Fig. 2  
*Poria ferrea* ex Central Experimental Farm, Canada, 11253, substratum unknown, Burnet, Quebec
- A. Mycelium in one-year-old red-gum wood-block cultures not forming a thin white rhizomorphic growth over wood test pieces; mycelium completely enveloping the blocks and masking them from view .. B
- B. Black or brown lines conspicuous in wood-block cultures  
*Poria punctata* on *Rhus vernix*, Michigan
- B. Black or brown lines not present, or at least not conspicuous in wood-block cultures  
*Poria prunicola* on *Prunus serotina*, Michigan. Pl. XIV, Fig. 3
22. Mycelium exhibiting a concentric ring growth at 25° C.  
*Trameetes isabellina* 10 W. on *Picea glauca*, Selkirk, Yukon Territory. Pl. XI, Fig. 2
22. Mycelium not exhibiting concentric ring growth at 25° C. .... 23
23. Culture uniformly brown in two-week-old tests
- A. Mycelium of uniform color in one-year-old red-gum block cultures  
*Poria Weirii* on *Thuja plicata*, locality not specified. Pl. XIV, Fig. 2
- A. Mycelium not uniform in color in one-year-old red-gum block cultures but varying in different shades of brown and appearing, because of color, patchy  
*Poria ferrugineofusca* on *Pseudotsuga taxifolia*, Oregon. Pl. XIV, Fig. 1

23. Culture predominantly white with areas of brown mycelium in two-week-old tests

*Poria ferrea* on *Salix* sp., Oregon (grows faster than all other isolates, i.e. 30 mm. at 25° C.). Pl. XII, Fig. 3

*Poria ferrea* on *Alnus rubra*, Oregon (20 mm. growth at 25° C.). Pl. XI, Fig. 4

*Poria ferrea* on *Acer macrophyllum*, Oregon (15 mm. growth at 25° C.). Pl. XII, Fig. 1

*Poria ferrea* on *Corylus* sp., Oregon (15 mm. growth at 25° C.). Pl. XII, Fig. 2

*Poria ferruginosa*<sup>1</sup> on *Acer saccharum*, Michigan (23 mm. growth at 25° C.). Pl. XIII, Fig. 1

*Poria ferruginosa* on *Prunus serotina*, Michigan. Pl. XIII, Fig. 3

*Poria ferruginosa* 33 on *Thuja plicata*, Oregon (15 mm. growth at 25° C.) Pl. XIII, Fig. 4

24. Isolates from coniferous woods

A. Mycelium on one-year-old red-gum block cultures forming a thin white rhizomorphic growth over the wood

*Poria ferruginosa* on *Thuja occidentalis*, Minnesota. Pl. XIII, Fig. 2

A. Mycelium in one-year-old red-gum block cultures not forming a thin white rhizomorphic growth over the wood

*Poria ferrugineofusca* on *Pseudotsuga taxifolia*, Oregon (not so whitish as western hemlock isolate; red-brown mycelium conspicuous). Pl. XIV, Fig. 1

*Poria ferrugineofusca* on *Tsuga heterophylla*, Skagway. (This isolate forms a cream-colored or whitish smooth mycelial mat over blocks with red-brown mycelium present in culture. Culture much more whitish than Douglas fir isolate)

24. Isolates from hardwoods

*Fomes robustus* on *Betula nigra*, Virginia (predominating colors of cultures mostly "warm buff" or "antimony yellow" as in *F. Everhartii*; no "plug" found as in *F. Everhartii*). Pl. XIV, Fig. 4

*Fomitiporia dryophila*, Race I, on *Quercus* sp., Florida (predominating colors of cultures yellower than those of *F. robustus* or *F. Everhartii*, i.e. "cream color" or

<sup>1</sup> *Poria ferruginosa* on *Thuja occidentalis* exhibits a growth of 25 mm. at 25° C. Since this isolate grows approximately 20 mm. at 30° C., it is not grouped here. The isolate on maple did not grow at 30° C.



"Naples yellow"; plugs of mycelium not formed as in *F. Everhartii*). Pl. V, Fig. 1  
*Fomes Everhartii* (form *dryophila*, undescribed) on *Quercus* sp., Oklahoma (mycelium growing so luxuriantly within flask that a distinct "plug" is formed which eventually envelops both agar and wood blocks so as to pull the media away from the bottom of the container). Pl. IX, Fig. 4

*Fomes Everhartii* on *Quercus imbricaria*, Michigan (mycelium growing so luxuriantly within flask that a distinct "plug" is formed which eventually envelops both agar and wood blocks so as to pull the media away from the bottom of the container). Pl. X, Fig. 1

25. Mycelium with wintergreen odor in two-week-old petri-dish cultures at 30° C.

A. Mycelium in one-year-old red-gum block cultures exhibiting nodular growth

*Poria laevigata* on *Acer* sp., Michigan (mycelium not forming growth over white-pine blocks in one-year-old tests). Pl. V, Fig. 4  
*Fomes nigricans* on *Betula alba papyrifera*, Minnesota (mycelium covering white-pine blocks in one-year-old tests, i.e. *Fomes nigricans* grows more readily on white pine than does the superficial mycelial growth of *Poria laevigata* over test pieces). Pl. VIII, Fig. 4

A. Mycelium in one-year-old red-gum block cultures not exhibiting nodular growth

*Fomitiporella floridana*?<sup>4</sup> Race I, on *Carpinus*, Great Falls, Virginia. (One-year-old cultures of all races of *Fomitiporella floridana* are more whitish than those of all races of *Fomitiporia Earleae*. The predominating colors of all races of *F. Earleae* are generally similar to those of *Fomes Everhartii*, i.e. mostly "warm buff" or "antimony yellow.") Pl. VII, Fig. 1

*Fomitiporia Earleae*,<sup>4</sup> Race II, on *Liquid-*

<sup>4</sup> The presence of red lines or red crustlike areas is common to the races of *Fomitiporella floridana* and of *Fomitiporia Earleae*. Wood-block cultures of these fungi that are one year old have demonstrated that the predominantly "hematite-red" areas that appear in cultures are not restricted to those of *Fomitiporia Earleae*, but occur in *Fomitiporella floridana* as well. These red areas or lines appear in wood-block cultures, but may not be evident in younger agar cultures.

*ambar Styraciflua*, Georgia. (This fungus exhibits a few black lines in one-year-old red-gum block cultures, mycelium not plugging up flasks. Slight or no winter-green odor, so that isolate is included in both sections of key. One-year-old cultures of all races of *Fomitiporia Earleae* are more yellowish than those of all races of *Fomitiporella floridana*. The predominating colors of *Fomitiporia Earleae* are not whitish, but similar to those of *Fomes Everhartii*, i.e. "warm buff" or "antimony yellow.") Pl. VIII, Fig. 2

*Poria laevigata* on *Betula occidentalis*, British Columbia. *P. betulina* is a synonym. (White pine blocks are either not at all or scarcely attacked by this fungus in one-year-old tests. This feature is generally characteristic for cultures of most isolates of *P. laevigata*, and it can be used to distinguish *P. laevigata* from all isolates listed in this section of the key. See also *P. laevigata*, section 25. *P. laevigata* from *Betula nigra* is an exception, however, since it does not grow on white pine. These two isolates can be separated from each other by the predominantly white mycelium of *P. laevigata* on *Betula nigra* and the yellowish mycelium of *P. laevigata* on *Betula occidentalis*. In general, isolates of this species grow faster at room temperature than those of *Fomes nigricans*.) Pl. VI, Fig. 1.

*Poria laevigata* on *Betula nigra*, Virginia. (Predominating colors of cultures more whitish than yellowish, but this feature does not apply to all isolates of *P. laevigata*. Unlike most isolates of *P. laevigata*, this one grows over white-pine blocks, in one-year-old cultures.) Pl. VI, Fig. 2

*Fomes nigricans* U. 42 on *Betula kenaica*, Moose Pass, Alaska (predominating

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Agar cultures have been described in Paper VIII (22 [1936]: 275-295) of this series.

The genera *Fomitiporia* and *Fomitiporella* are separated by W. A. Murrill, "Polyporaceae," *North American Flora*, 9 (Part I, 1907; Part II, 1908): 1-131 on the basis of spore color. The spores are said to be hyaline in *Fomitiporia* and brown in *Fomitiporella*. The specimens have been compared with the types, but since spore color is often hyaline at first and later brown in some of the specimens of these genera, it was believed best to reserve the revision of species and generic concepts of these groups for a later study.

colors of cultures more yellowish than whitish, but this feature does not apply to all isolates of *Fomes nigricans*).

25. Mycelium without wintergreen odor in two-week-old petri-dish cultures at 30° C.

- A. Mycelium in one-year-old red-gum block cultures growing so luxuriantly that the flask is practically filled with mycelium and often forming so that entire flask is filled with fungous growth; blocks usually hidden from view completely

*Fomes Everhartii* (form *dryophila*, undescribed) on *Quercus* sp., Oklahoma. (Lines more black or brown than purplish and not abundant enough to form large patched or red or purplish areas. Predominating colors of cultures are "warm buff" or "antimony yellow." Mycelium growing so luxuriantly that even the agar is drawn away from the flask and enveloped so as to form a "plug.") Pl. IX, Fig. 4

*Fomes Everhartii* on *Quercus imbricaria*, Michigan. (Lines more black or brown than purplish, present but not abundant enough to form large purplish patches. Predominating colors of cultures are "warm buff" or "antimony yellow." Mycelium growing so luxuriantly that even the agar is drawn away from the flask and enveloped so as to form a "plug.") Pl. X, Fig. 1

*Fomes robustus* on *Betula nigra*, Virginia. (Lines more black or brown than purple and not abundant enough to form large purple patches. Mycelium exhibiting luxuriant growth, but not to the extent that the shapes of the blocks are so masked as to be entirely hidden from view as in *Fomes Everhartii* isolates. Mycelium not so luxuriant that even the agar is drawn away from the flask and enveloped to form a "plug.") Pl. XIV, Fig. 4

Unknown *Poria* on *Quercus laurifolia*, Florida. (Lines more purplish than black or brown, abundant enough to form large areas of purple patches. Shape of block hidden from view. Mycelium not growing so luxuriantly that even the agar is drawn away from the flask and enveloped so as to form a "plug.") Pl. VII, Fig. 4

- A. Mycelium in one-year-old red-gum block cultures not so luxuriant that the flask is filled with mycelium, general shape of blocks not

hidden from view by fungous growth, plug of mycelium not forming, i.e. mycelium not clinging to walls of flask but often supporting both agar and blocks

*Fomes robustus* on *Betula nigra*, Virginia (predominating colors of cultures mostly "warm buff" or "antimony yellow," as in *F. Everhartii*). Pl. XIV, Fig. 4

*Fomitiporia dryophila*, Race I, on *Quercus* sp., Florida (predominating colors of cultures more yellow than those of *F. robustus* or *F. Everhartii*, i.e. "cream color" or "Naples yellow." "Plugs" of mycelium not formed as in *F. Everhartii*). Pl. V, Fig. 1

*Fomitiporia Earleae*, Race II, on *Liquidambar styraciflua* (predominating colors of cultures are those of *F. robustus*<sup>\*</sup> and *F. Everhartii*). Pl. VIII, Fig. 2

#### UNIVERSITY OF MICHIGAN

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<sup>\*</sup> The fruiting bodies of *Fomitiporia Earleae* and *Fomes robustus* have much in common, and the two fungi are so very closely related that present distinctions may not warrant their separation, at least with reference to specific differences. One may be a resupinate or some other form or race of the other. Fruiting bodies of *F. Earleae* are more likely to refract light than those of *Fomes dryophilus*, but this feature, like other characters of both the fruiting bodies and mycelium in culture, appears relative.

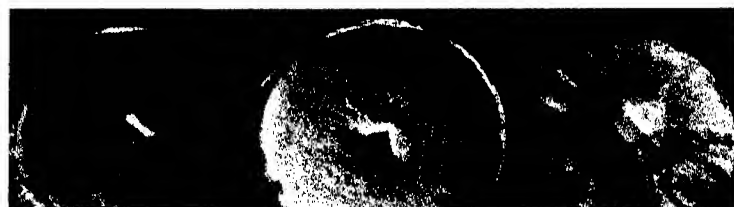
**PLATES I-XIV**



*Poria rufa* on *Picea glauca*, Fort Wrigley, Northwest Territories



*Lenzites trabea* from United States Division of Forest Pathology,  
Forest Products Laboratory, Madison



*Poria unila* on *Quercus* sp., Michigan



*Poria unila pulchella*, Selkirk, Yukon Territory

Cultures kept at 25°, 30°, and 35° for 14 days





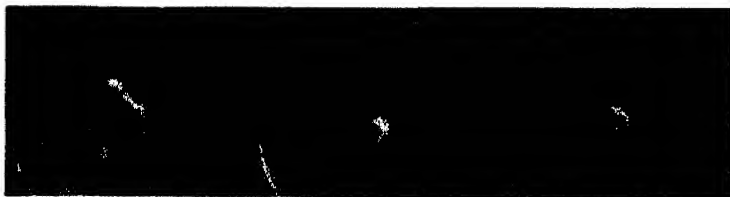
*Poria unita pulchella*, U. 26, on *Populus balsamifera*, Burnt Island,  
Great Slave Lake, Northwest Territories



*Polyporus alboluteus* on *Picea sitchensis*, Juneau, Alaska



*Poria spissa*, substratum unknown, Michigan



*Poria semitincta*, U. 23 (growth variable), on *Quercus marilandica*,  
North Carolina

Cultures kept at 25°, 30°, and 35° for 14 days







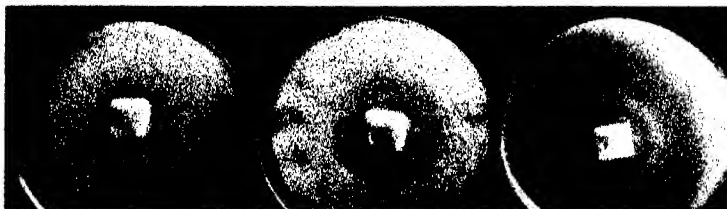
*Poria mulans tenuis* on *Castanea dentata*, Georgia



*Poria incrassata* from United States Division of Forest Pathology,  
Forest Products Laboratory, Madison



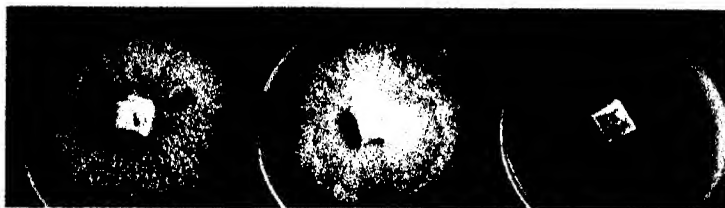
*Poria eupora* on *Quercus borealis maxima*, Michigan



*Poria luteofibrata* on *Pinus rigida serotina*, Florida

Cultures kept at 25°, 30°, and 35° for 14 days





*Fomes subroseus* on *Larix laricina*, Michigan



*Poria purpurea* on *Pinus contorta*, Jasper National Park, Alberta



*Poria nigra*, from United States Division of Forest Pathology,  
Washington, 71073



*Poria nigra*, growth variable at 35° C., from United States Division  
of Forest Pathology, Washington, 71099, on *Quercus velutina*, Illinois

Cultures kept at 25°, 30°, and 35° for 14 days





*Fomitiporia dryophila*, Race I, on *Quercus* sp., Florida



*Fomitiporia dryophila*, Race II, on *Carpinus*, Louisiana



*Poria spiculosa* on *Carya* sp., from United States Division  
of Forest Pathology, Washington



*Poria laevigata* on *Acer* sp., Michigan

Cultures kept at 25°, 30°, and 35° for 14 days





*Poria laevigata* on *Betula occidentalis*, British Columbia



*Poria laevigata* on *Betula nigra*, Virginia



*Fomitiporia flavomarginata* on *Quercus nigra*, South Carolina

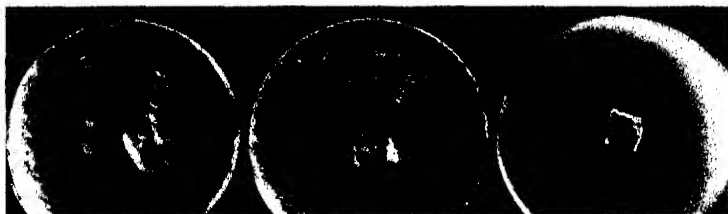


*Lenzites saepiarum* on *Picea mariana*, Michigan

Cultures kept at 25°, 30°, and 35° for 14 days







*Fomitiporella floridana* ?, Race I, on *Carpinus*, Virginia



*Fomitiporella floridana*, Race II, on *Quercus phellos*, Arkansas



*Fomitiporella floridana*, Race I, on *Quercus nigra*, South Carolina



Unknown *Poria* on *Quercus laurifolia*, Florida

Cultures kept at 25°, 30°, and 35° for 14 days





*Fomitiporia Earleae*, Race I, on *Nyssa biflora*, Florida



*Fomitiporia Earleae*, Race II, on *Liquidambar styraciflua*, Georgia



Unknown resupinate X on *Betula kenaica*, Moose Pass, Alaska



*Fomes nigricans* on *Betula alba papyrifera*, Minnesota

Cultures kept at 25°, 30°, and 35° for 14 days





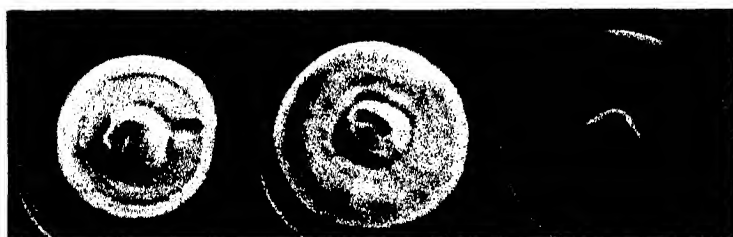
*Fomes nigrolimitatus* 8 F. on *Tsuga heterophylla*, Wrangell, Alaska



*Polyporus radiatus* on *Betula kenaica*, Moose Pass, Alaska



*Fomes Everhartii* on *Quercus borealis maxima*, Michigan



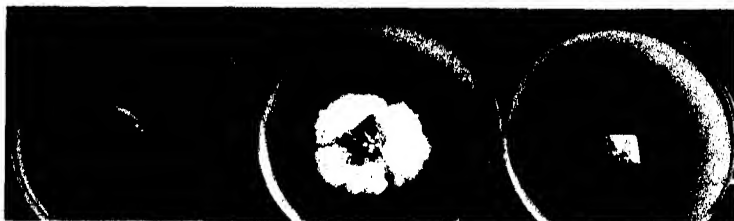
*Fomes Everhartii* (form *dryophila*, undescribed) *Quercus* sp., Oklahoma

Cultures kept at 25°, 30°, and 35° for 14 days





*Fomes Everhartii* on *Quercus imbricaria*, Michigan



*Poria Tsugina* on *Abies concolor*, Colorado



*Poria Tsugina* on *Tsuga heterophylla*, British Columbia



*Poria Tsugina* on *Tsuga canadensis*, Michigan

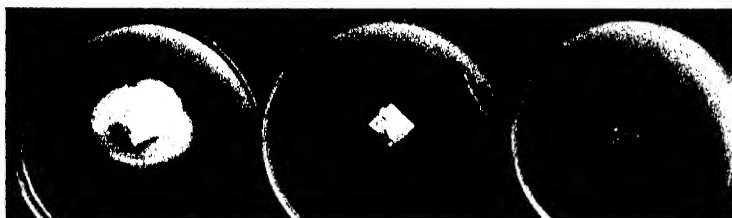
Cultures kept at 25°, 30°, and 35° for 14 days







*Trametes isabellina* 6 W. on *Picea glauca*, Selkirk, Yukon Territory



*Trametes isabellina* 10 W. on *Picea glauca*, Selkirk, Yukon Territory



*Poria ferrea* on *Alnus sinuata*, Skagway, Alaska



*Poria ferrea* on *Alnus rubra*, Oregon

Cultures kept at 25°, 30°, and 35° for 14 days





*Poria ferrea* on *Acer macrophyllum*, Oregon



*Poria ferrea* on *Corylus* sp., Oregon



*Poria ferrea* on *Salix* sp., Oregon



*Poria ferrea* 9 on *Abies* sp., Oregon

Cultures kept at 25°, 30°, and 35° for 14 days





*Poria ferruginosa* on *Acer saccharum*, Michigan



*Poria ferruginosa* on *Thuja occidentalis*, Minnesota



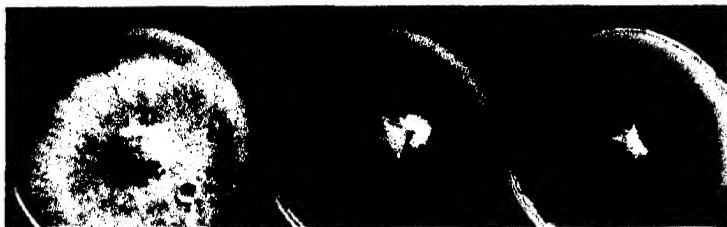
*Poria ferruginosa* (variable growth at 25° C.) on *Prunus serotina*, Michigan



*Poria ferruginosa* 33 on *Thuja plicata*, Oregon

Cultures kept at 25°, 30°, and 35° for 14 days





*Poria ferrugineofusca* on *Pseudotsuga taxifolia*, Oregon



*Poria Weirii* on *Thuja plicata*



*Poria prunicola* on *Prunus serotina*, Michigan



*Fomes robustus* on *Betula nigra*, Virginia

Cultures kept at 25°, 30°, and 35° for 14 days





## PRESENT INDICATIONS OF FUTURE TRENDS IN MICHIGAN FOREST INDUSTRIES

MURLYN B. DICKERMAN

**E**VERY national crisis produces important changes in our economic life. Already there are many indications that the impact of World War II upon the forest industries has forced new trends and adjustments. It is worth while to analyze these new trends and to determine whether they will be carried over into peacetime, and if so, what effect they will have upon the industries themselves and the forest resource on which they depend.

Michigan, producing nearly half of all the lumber in the Lake States, is a strategic state in which to observe these developments. The Upper Peninsula is one of the few important centers of hardwood-lumber production. Veneer cut in this area supplies a large part of the hardwood-veneer requirements for the airplane construction program of the United Nations. Nearly 40 per cent of the total facilities of the hardwood-distillation industry in this country is located in Michigan. Although the manufacture of wood pulp is small when compared with the total produced in the Lake States, some of the specialty papers made at Michigan mills are among the items most urgently needed by the Army and Navy. In these primary forest industries changes can be observed. The following are some of the most significant ones.

### THE GROWING IMPORTANCE OF SMALL SAWMILLS

One of the most noticeable tendencies since the war has been the relative increase in the total volume of lumber cut by small mills<sup>1</sup> (Fig. 1). In 1941 these mills sawed nearly a third of the lumber. By 1943 their output amounted to almost half of the entire lumber production in the state. This shift, although evident prior to the war, has been greatly accelerated during the war, and

<sup>1</sup> The term "small mills" refers to sawmills cutting less than five million board feet of lumber annually.

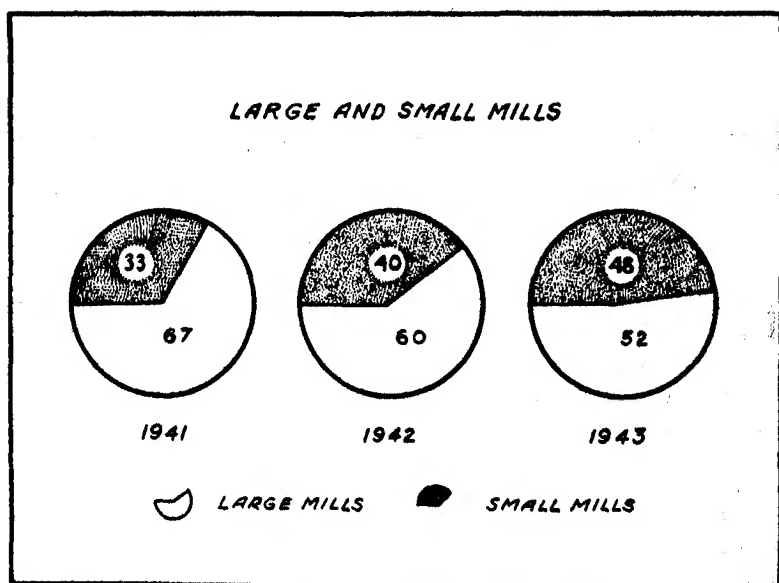


FIG. 1. Percentage of total yearly lumber production cut in Michigan in 1941, 1942, and 1943 by large and small mills

the prospects are that the percentage coming from small mills in the future will be even greater.

There are several reasons for this increase. Since 1941 four of the large sawmills in the Upper Peninsula have closed permanently and are in the process of liquidating their plants. Practically none of the large mills has operated continuously at full capacity, and only one or two have been able to run more than one shift a day. Furthermore, the depletion of adjoining timber tracts, shortages of manpower and equipment, and high operating costs have retarded lumber production in large mills more than in small ones.

On the other hand, during this period small mills have shown a remarkable ability to turn out lumber. In lower Michigan, for example, where there are more than four hundred small mills, the output in the last six months of 1943 was 26 per cent greater than in the same period of 1942, while that in large mills in the Upper Peninsula was 23 per cent less.

There may be some concern regarding the quality of the lumber

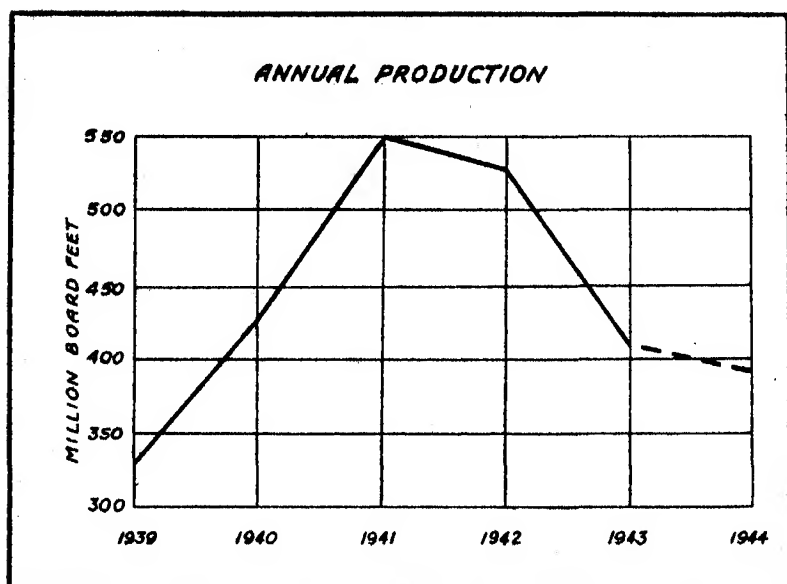


FIG. 2. Annual lumber production of Michigan during the first years of World War II

from small mills. The record during the past two years (1942-44) indicates that well-built and permanently established sawmills, operated by competent mill crews, are fully capable of making high-grade material. Some of the best lumber now going into the war industries is coming from small band and circular mills cutting one to two million feet a year.

After the war the labor supply will undoubtedly be plentiful, and equipment shortages will soon be overcome. But the absence of large timber tracts and the probability that the remaining timber will be located on the more difficult logging "chances" and in relatively small quantities will tend to center more and more lumber operations in small mills. Although a shift from large to small mills will increase proportionately the output of the small mills, it is inevitable that the annual cut in the postwar period will be less. Already lumber production in Michigan has dropped 26 per cent — from 550 million board feet in 1941 to about 415 million in 1943 (Fig. 2).

This swing toward small mills is to be desired from both the economic and the forest-utilization standpoint. In most areas these mills can be readily supplied on a sustained basis because their log requirements are more nearly in balance with available timber supplies. Under such a condition small sawmills can become a permanent part of local industrial life, making possible fuller use of available forest resources and assuring steady employment and stability to communities in rural areas.

#### MORE SAWMILLS MANUFACTURING SECONDARY WOOD PRODUCTS

Closely connected with the growing importance of the small mill is the increasing number of sawmills which are combining with the sawing of rough lumber the manufacture of secondary wood products. This movement is particularly noticeable in lower Michigan and to some extent in the Upper Peninsula. One sawmill, for instance, is making parts for farm implements, such as hayracks, shovel and rake handles, wagon bodies, and stoneboats. Another has installed an automatic lathe to make wood turnings, while others are assembling such items as factory truck platforms, door mats, onion and celery crates, and railroad and mine wedges. Two small mills are reworking industrial blocking, cutting it to the final size, boring holes at proper spacings, and shaping for blocking railroad shipments of heavy machinery.

Now that these mills and others have found they can manufacture such items and have developed trade relations with industrial and agricultural outlets, it is likely that many similar articles will continue to be made by small concerns after the war. Greater returns from manufacturing secondary products will be a further reason for sawmills to engage in this type of work. Furthermore, although low-grade lumber is temporarily in big demand, there is no question that sawmill operators will again be faced with the problem of finding a market for their lower grades. By cutting up this material and prefabricating it some of the difficulties of marketing low-grade lumber can be overcome.

The combination of primary and secondary processing means closer utilization of both woods and mill waste, a factor which can help to make better forest practices pay and give part-time employment to many people in rural areas. This should be encouraged and receive further development.

**GREATER UTILIZATION OF HEMLOCK LOGS IN PULP MILLS**

The reduction of pulpwood receipts, from both domestic and Canadian sources, and the increased requirements for wood pulp are major problems of Michigan pulp mills and will likely continue to be. Since January, 1943, pulpwood inventories in Michigan have declined 33 per cent, and half of the pulp mills in the state now have less than a three months' supply of wood. In part, this shortage can be explained by a steady decline in the volume of wood received from Canadian sources, but equally serious has been the declining production of pulpwood in Michigan.

Partly to offset these shortages, a number of pulp mills in Michigan and Wisconsin have increased their consumption of hemlock logs for the manufacture of wood pulp. In 1941 only 29 per cent of the hemlock cut in Michigan was converted into wood pulp, but by 1943 nearly 43 per cent of the hemlock was used this way (Fig. 3). The rest was purchased by sawmills for lumber.

Hemlock timber will continue to be one of the best sources of domestic pulpwood for Michigan and Wisconsin pulp mills, for the amount of hemlock timber left in the Upper Peninsula is greater than that of any other pulpwood species. Michigan pulp mills will face stiff competition from the sawmills for the saw-log material, even though much of it is best suited for use as pulpwood. They will also have to compete with Wisconsin pulp mills, for much of the remaining hemlock is in the western part of the Upper Peninsula nearer Wisconsin markets. The only other prospect of obtaining a sufficient supply of pulpwood is the possibility that Canada may lift the restrictions on the exportation of wood. However, in view of the large supply of hemlock timber in Michigan, the increased requirements for wood pulp, and the shortage of pulpwood inventories, it is highly probable that the present trend of using more hemlock will continue.

**DECLINE OF THE HARDWOOD-DISTILLATION INDUSTRY**

With the products from the chemical conversion of wood occupying an important place in the manufacture of many essential commodities, it is somewhat strange that hardwood distillation is declining. Shortly before World War II started one hardwood distillation plant in Michigan closed; in the past year two more have shut

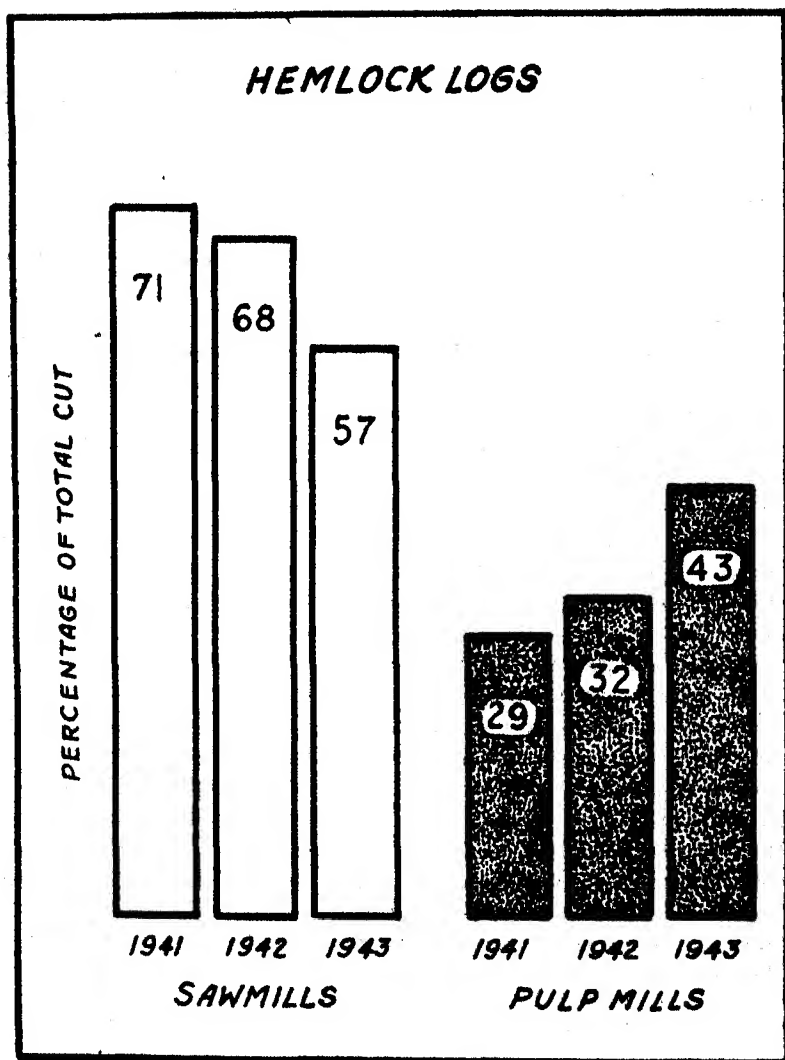


FIG. 3. Distribution of total cut of hemlock logs in Michigan to sawmills and pulp mills

down and are now being dismantled. This leaves only three plants in the state. During the last twelve months these have been operating at less than half of their rated annual capacity.

Among the main factors influencing this decline has been the difficulty of obtaining necessary supplies of wood. The cutting of chemical wood has never been a remunerative occupation, and the migration of woods labor to better-paying jobs during the war has made it difficult to get wood cut and hauled to chemical plants. Also, this shortage has been accentuated by the depletion of chemical wood supplies near the distillation plants, and high freight rates have prohibited hauling it from more distant points where it could have been obtained. However, with the large areas of second-growth hardwoods coming in on the cutover lands, and an increase in the labor supply after the war, the supply problem should be eased. If some adjustment can be obtained in freight rates so that wood can be hauled to existing distillation plants, there should be more than enough raw material to meet the future needs of the industry.

Yet the future of the industry is not at all certain. Apparently the difficulty lies in the inability of wood chemical plants to compete successfully with the synthetic manufacture of acetic acid and alcohol. Although having a monopoly on charcoal production should be helpful, the returns from charcoal alone are not enough to cover the operating costs. Indications are that unless through research new processes and diversified products are found, only the best-equipped and the most efficient hardwood distillation plants will survive. The decline of this market will be a severe blow to good forest practices because it provides one of the best markets for inferior species, tops of trees, thinnings, and cull logs.

#### LEVELING-OUT OF SEASONAL LUMBER PRODUCTION

Another trend, the implications of which are not yet entirely clear, is the leveling-out of the monthly lumber production since June, 1942. Instead of having high and low periods, the tendency has been for the industry to operate more steadily throughout the year. This became most noticeable in the first half of 1943, when in place of the usual big drop in the spring months there was a gradual increase (Fig. 4). For the rest of the year it was about the same. Whether or not this is only a temporary periodic shift is, as yet, difficult to say, but at least the advantages are many.



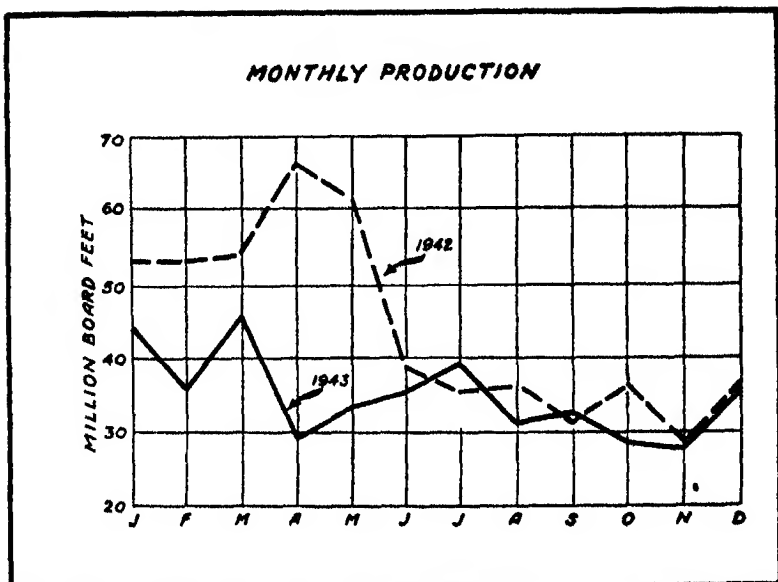


Fig. 4. Monthly lumber production of Michigan sawmills in 1942 and 1943

This elimination of the high and low periods in 1943 can to some degree be accounted for by the shortage of manpower. In trying to keep their crews together employers had to provide steady work for them. Whether in the postwar period, with an ample supply of labor, this practice will continue is not certain, but all-year employment does eliminate the disadvantages of seasonal work. It helps to develop skilled logging and mill crews, and that means greater efficiency and higher quality lumber. Furthermore, steady month-to-month output will lower operating costs, for in both sawmills and small secondary wood-using plants economy frequently depends upon the full and continuous use of plant facilities.

The lumber industry in the State of Michigan has demonstrated that it can operate on a relatively stable year-round basis. There is every reason to believe that what has been done under war conditions can also be accomplished in peacetime.

These are a few of the new trends and adjustments which are coming to the front in the forest industries of the state under the

stress of war. If they are found to be economically sound, they may be continued into peacetime and, to some extent, may help to compensate for the strains of the war period. By recognizing these changes early and anticipating the adjustments that inevitably will follow, the forest industries, managers of forest land, and local governments should be in a better position to plan for the future.

FOREST SERVICE, DEPARTMENT OF AGRICULTURE  
LAKE STATES FOREST EXPERIMENT STATION  
UNIVERSITY FARM, ST. PAUL, MINNESOTA



# ZOOLOGY



## GROWTH POTENTIAL OF THE NORTHERN PIKE (*ESOX LUCIUS*)\*

WILLIAM F. CARBINE

IT HAS long been known that most fishes have an indeterminate type of growth, but it has only recently been appreciated that their potential rate of increase is vastly greater than their average growth in nature. Since fishes are also notably subject to dwarfing under conditions of overpopulation, extreme competition, and restricted space, it follows that the variation of size at a given age may be enormous. It is also known that a reduced growth in early life does not destroy the growth potential, for when placed under favorable conditions the dwarfed fish may grow at an unusually rapid rate. These phenomena have been determined chiefly through studies using the scale method of estimating age, but may be more directly and conclusively investigated by experiments. The present paper reports data relating to the growth of the northern pike obtained during the course of experiments conducted from 1937 to 1939. The results bear on each of the growth tendencies mentioned above.

These experiments were undertaken by the Institute for Fisheries Research of the Michigan Department of Conservation to obtain information on the possibility of artificially propagating northern pike. The data on the fish cultural problem will be reported elsewhere. The work was done at the Drayton Plains Hatchery, with the effective coöperation of A. T. Stewart, then District Fisheries Supervisor, and his staff. Thanks are also due to Dr. Albert S. Hazzard, Director of the Institute for Fisheries Research, for assistance in planning the work. I should like to express my appreciation to Dr. Carl L. Hubbs for aid in the analysis of the data and for suggestions and help in the preparation of this report.

The northern pike used in this experiment were hatched from eggs taken on April 7 and 8, 1937, at Walled Lake, Oakland County.

\* Contribution from the Institute for Fisheries Research of the Michigan Department of Conservation.

On May 3 about 150,000 fry were stocked in the Ortonville Rearing Pond, which has an area of nearly three acres, an average depth of two and one-half feet, and a maximum depth of eight feet. Food for the growing pike was furnished by the introduction of 6,200 small minnows on June 2. On June 16 the pond was stocked with 30,000 largemouth-bass fry, and some of these were probably eaten by the northern pike. Sometime during the spring, probably during a period of heavy rainfall in early June, large numbers of fish, of nineteen species, gained access to the pond, and doubtless contributed to the nourishment of the pike. All the fish thus accidentally introduced, with the exception of 850 yearling bluegills, were young of the year. The yearling bluegills spawned successfully in the pond and produced a large number of young, which further augmented the already abundant food supply. The known source of these extraneous fish, along with other circumstances, makes it virtually certain that no pike were included.

Samples of the pike, seined on June 25, July 14, and August 17, were preserved to determine the length and weight. Of about 100 netted on the first date a random series of 40 was preserved. All the fish that could be seined on the other dates, 21 on July 14 and 12 on August 17, were kept (the soft bottom and the dense growth of plants made collecting difficult). When the pond was drained on October 14, 362 pike were recovered, along with many small minnows and bluegills. All these fish were individually weighed and measured.

A tremendous spread in length developed early in the growing season (Table I; Figs. 1-2; Pl. I). The pike in the June 25 sample ranged from 50 to 135 mm.; those in the July 14 series, from 62 to 222 mm.; those in the August 17 sample, from 79 to 263 mm. It is possible that the largest and smallest individuals in the pond on these dates escaped capture. The 362 fish remaining on October 14 had the unprecedented size range of 83 to 446 mm. (Pl. II), with the average at 207.2 mm. The great divergence in size obviously increased as the summer advanced. Many of the pike grew very rapidly and quite variably; others grew little and formed a very compact-sized group (Fig. 1).

The survival and growth of these pike in the Ortonville Pond followed the pattern of other highly predaceous fishes in pond culture. A few of the fish got a better start and grow to large and

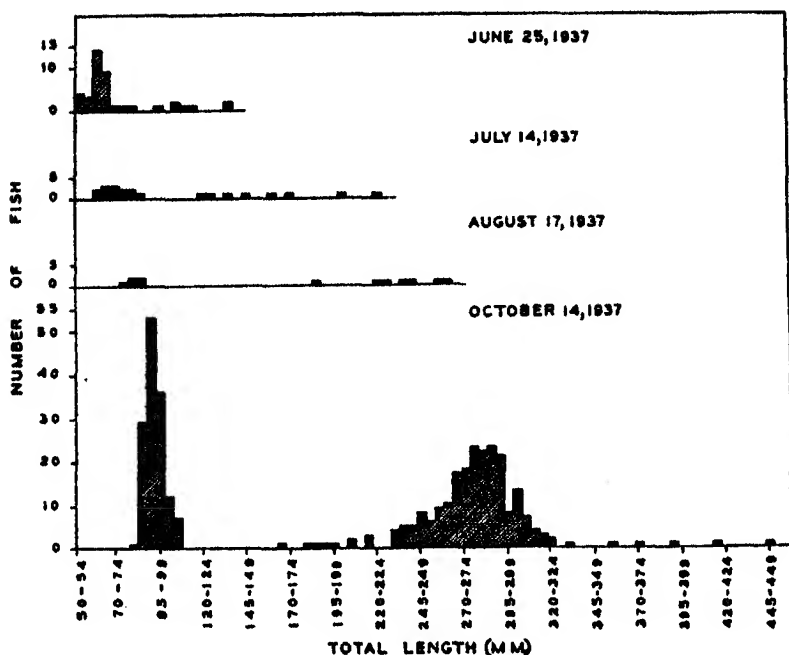


FIG. 1. Histogram showing the growth of the northern pike in the Ortonville Rearing Pond

variable sizes. Others, with a poorer start, find the competition so severe that they remain small and uniform in length. Cooper's study (1937) of pond-cultured largemouth bass illustrates these relations.

The largest fish taken on October 14 had grown at an average rate of 2.6 mm. (0.1 inch) per day. The largest fish at each collection date during the summer were all growing at a rate of more than 2.0 mm. per day, and the largest fish taken on July 14 was growing at a slightly faster rate (2.7 mm. per day) than the largest specimen taken on October 14 (Table I). Other workers (Embrey, 1915; Webster, 1929; Rawson, 1932; Van Engel, 1940; Elson, 1941) have found that the northern pike and the muskellunge, a very close relative of the northern pike, are capable of exceedingly rapid growth. During part of the first season pike in nature grow as much as 3.3 mm. per day (Carbine, 1942). The only comparable rate of



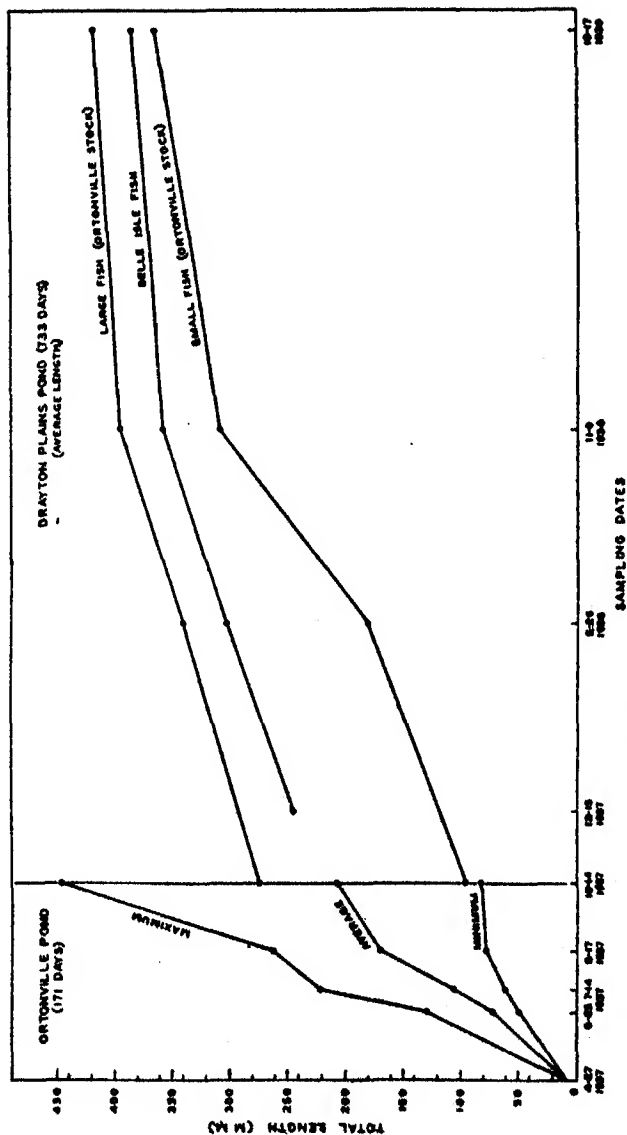


FIG. 2. Growth in length of the northern pike in rearing ponds at Ortonville and Drayton Plains

TABLE I  
GROWTH OF THE NORTHERN PIKE IN THE ORTONVILLE POND FROM THE TIME OF HATCHING  
ON APRIL 27 UNTIL OCTOBER 14, 1937

| Sampling date | Number of fish in sample | Age (days) | Total length (mm.) |         | Growth per day (mm.) * |       | Weight (grams) |        | Growth per day (grams) |        |
|---------------|--------------------------|------------|--------------------|---------|------------------------|-------|----------------|--------|------------------------|--------|
|               |                          |            | Range              | (Av.)   | Range                  | (Av.) | Range          | (Av.)  | Range                  | (Av.)  |
| June 25       | 40                       | 60         | 50-135             | (72.6)  | 0.7-2.1                | (1.1) | -13            | ...    | -0.22                  | ...    |
| July 14       | 21                       | 79         | 62-222             | (107.0) | 0.7-2.7                | (1.2) | 1-78           | (13.4) | 0.01-0.99              | (0.17) |
| Aug. 17       | 12                       | 113        | 79-263             | (171.0) | 0.6-2.2                | (1.4) | 2-102          | (46.7) | 0.02-0.90              | (0.41) |
| Oct. 14       | 362                      | 171        | 83-446             | (207.2) | 0.4-2.6                | (1.2) | 2-460          | (72.1) | 0.01-2.69              | (0.42) |

\* Northern pike are approximately 9 mm. long when hatched.

early growth per day which has been published is for the longnose gar, *Lepisosteus osseus* (Hubbs, 1921).

The diversity of growth in weight of the northern pike in the Ortonville Pond was even more striking (Table I; Fig. 3). On October 14 the smallest specimen weighed only 2 grams; the largest one, 460 grams (just over a pound). The 362 northern pike remaining on October 14 had grown an average of 0.42 gram in weight per day during the 171 days since hatching. The largest fish (460 grams) grew at the rate of 2.69 grams per day during this same period.

The extremely rapid growth of some of the pike in the Ortonville Pond is an example of the great growth potential possessed by fishes. The large food supply, warm temperature, and other conditions were obviously conducive to exceptionally rapid growth. Why, then, did some of the fish become stunted in the same pond, to produce the striking divergence in size? Several reasons come to mind.

It is possible that the small fish were diseased, though the evidence available does not favor this explanation. They were obviously emaciated, and all but 6 of the 140 died within five days after the removal of the fish from the Ortonville Pond to the Drayton Plains Hatchery, whereas none of the larger fish, treated in the same way, died during this period. Examination of those that died by Lowell A. Woodbury disclosed no external or internal parasites that could be regarded as responsible for the mortality. It is also possible, though inherently improbable, that the dwarfed fish had never learned to eat. Another theoretical possibility, that the dwarfs failed to grow because of genetic factors, is negated by the rapid growth made during the next season (p. 215). Overcrowding and the space factor may have contributed to the dwarfing of some of the pike in the pond, but such an explanation would be inconsistent with the very rapid growth of other pike in the same pond.

The most plausible explanation for the great diversity in size of the pike in the Ortonville Pond is that some of the fish obtained an advantage in feeding that was maintained through the season, whereas others lived under conditions that were unfavorable. An early start, due to hatching a day earlier or to earlier assumption of predation, may have given certain fish an initial advantage. Some may have taken up a habitat where food conditions were excellent, whereas others may have become established, either by random choice

or because other places were preëmpted, in sites where there was little food. In support of this view evidence may be cited that the young of the northern pike and the muskellunge do occupy definite home ranges of limited extent. While conducting another northern-pike experiment at Drayton Plains Hatchery in 1939 I learned that young pike could be found throughout the summer in definite spots about the pond. Similarly, Elson (1941) discovered that young muskellunge nearly always frequented certain well-defined areas. According to him, the young muskellunge do not range widely in search of food, but wait for the food organisms to come to them. He also noted that in trapping fingerlings one setting of a net would take two or more individuals, but several days intervened between the catches. He likewise stated that a lead of forty or fifty feet in length was no more effective on traps than a lead half that length. These observations suggest that the foraging range of the muskellunge is limited, and this evidence presumably applies also to the closely related northern pike. An early fixation of the feeding ranges, some favorable and others unfavorable, might well lead to differential growth.

The presence of the other nineteen species of fish in the pond brought about severe competition for food. Although an abundance of small fish was present, perhaps the largemouth bass and the perch were more adept at catching small fish than the small northern pike were. In an experiment to test the relationship between muskellunge fry and the fry of other species Elson (1941) placed muskellunge fry and largemouth-bass fry in the same container. Until the end of July they showed no inclination to molest each other, but competition for food was keen. The largemouth-bass fry were much more adept at capturing small minnows than the muskellunge were.

In discussing the feeding habits of the muskellunge MacKay and Werner (1934:315) stated: "Due to this habit of poising over its prey, the maskinonge often loses its victim, since the minnow fry are usually quite active and either swim away in the meantime or have started to swim away when the lunge strike, causing the latter to miss or obtain an insecure hold. Furthermore, the lateral body movements of the swimming minnow make it difficult for the maskinonge to strike accurately." The habits of the northern pike are very similar to those of the muskellunge, and it is believed that these observations made on the muskellunge apply to the northern pike.

It is therefore probable that the small northern pike in the Ortonville Pond were so weak and emaciated that they were not strong enough to catch minnows and were forced to subsist on inadequate food.

Further data on the growth of the northern pike were obtained at the Drayton Plains Hatchery, where the 6 survivors of the 140 small fish and 103 of the large fish that were taken in the draining of the Ortonville Pond on October 14, 1937, were kept in a pond until October 17, 1939. On December 15, 1937, 51 northern pike that were received from the Belle Isle Aquarium in Detroit were placed in the same pond with the other northern pike. The three series of pike were marked for future identification by clipping different fins for each lot. During the course of the experiment 65,295 minnows and perch were placed in the pond as food for the pike. Adult bluegills, which were also introduced, spawned successfully in the pond and produced an additional source of food. The pond was partly drained on May 26 and November 9, 1938, on which dates all the pike were counted and each lot was weighed as a unit, but individual weights and measurements of length were taken on only a random sample. All the pike were individually weighed and measured on October 17, 1939, when the pond was completely drained.

The tremendous growth made by some of the northern pike in the Ortonville Pond was not maintained throughout their retention at the Drayton Plains Hatchery (Table II; Figs. 2-5). The average growth increments in the rearing pond at the Drayton Plains Hatchery were as follows: 63.1 mm. from October 14, 1937, to May 26, 1938; 58.2 mm. from May 26 to November 9, 1938; 121.25 mm. for the first year; and only 26.3 mm. for the second year in the pond, from November 9, 1938, to October 17, 1939. These fish, therefore, made excellent growth during their first winter and first summer in the Drayton Plains Hatchery, but the increase in growth during the second full year was only 21.7 per cent of that of the first year. The marked decrease in the growth rate of the pike during their third year of life in a rearing pond caused them to be smaller than average at that age and made an unusually abrupt depression of the growth curve for the third year. By the end of their third summer, on October 17, 1939, the three groups in the Drayton Plains Hatchery ranged in average length from 14.3 to 16.4 inches, whereas in natural waters in Michigan northern pike usually reach the legal length of

TABLE II

GROWTH OF THE NORTHERN PIKE IN POND NO. 3 AT THE DRAYTON PLAINS HATCHERY  
BETWEEN OCTOBER 14, 1937, AND OCTOBER 17, 1939

| Sampling<br>dates *           | Total length (mm.) |         | Increment †<br>of average<br>length (mm.) | Pct. incre-<br>ment of<br>average<br>length | Average<br>weight<br>(grams) | Increment<br>of average<br>weight<br>(grams) | Pct. incre-<br>ment of<br>average<br>weight | Average growth<br>per day |       |
|-------------------------------|--------------------|---------|-------------------------------------------|---------------------------------------------|------------------------------|----------------------------------------------|---------------------------------------------|---------------------------|-------|
|                               | Range              | (Av.)   |                                           |                                             |                              |                                              |                                             | Mm.                       | Grams |
| Small fish (Ortonville stock) |                    |         |                                           |                                             |                              |                                              |                                             |                           |       |
| Oct. 14, 1937                 | 87-109             | (95.6)  | 86.6                                      | 91                                          | 4.1                          | 4.1                                          | 100                                         | 0.51                      | 0.02  |
| May 26, 1938                  | 160-197            | (172.7) | 84.1                                      | 47                                          | 31.6                         | 27.5                                         | 87                                          | 0.38                      | 0.12  |
| Nov. 9, 1938                  | 254-336            | (307.2) | 127.5                                     | 42                                          | 145.2                        | 113.6                                        | 78                                          | 0.76                      | 0.68  |
| Oct. 17, 1939                 | 356-373            | (363.8) | 56.6                                      | 16                                          | 230.0                        | 84.8                                         | 37                                          | 0.17                      | 0.25  |
| Large fish (Ortonville stock) |                    |         |                                           |                                             |                              |                                              |                                             |                           |       |
| Oct. 14, 1937                 | 195-371            | (274.1) | 265.1                                     | 97                                          | 101.3                        | 101.3                                        | 100                                         | 1.55                      | 0.59  |
| May 26, 1938                  | 297-385            | (339.1) | 65.0                                      | 19                                          | 227.5                        | 126.2                                        | 55                                          | 0.29                      | 0.56  |
| Nov. 9, 1938                  | 347-535            | (394.0) | 54.9                                      | 14                                          | 319.2                        | 91.7                                         | 29                                          | 0.33                      | 0.49  |
| Oct. 17, 1939                 | 260-652†           | (417.1) | 23.1                                      | 6                                           | 361.7                        | 42.5                                         | 12                                          | 0.07                      | 0.12  |
| Belle Isle fish               |                    |         |                                           |                                             |                              |                                              |                                             |                           |       |
| Dec. 15, 1937                 | 209-305            | (245.2) | 236.2                                     | 96                                          | 61.9                         | 61.9                                         | 100                                         | ...                       | ...   |
| May 26, 1938                  | 272-326            | (301.6) | 56.4                                      | 19                                          | 168.4                        | 106.5                                        | 63                                          | 0.35                      | 0.66  |
| Nov. 9, 1938                  | 324-396            | (356.5) | 54.9                                      | 15                                          | 234.0                        | 65.6                                         | 28                                          | 0.33                      | 0.39  |
| Oct. 17, 1939                 | 357-420            | (384.3) | 27.8                                      | 7                                           | 267.3                        | 33.3                                         | 12                                          | 0.08                      | 0.10  |

\* A random sample of fish taken on May 26 and November 9, 1938, was measured; all fish were weighed and counted.

† The eggs hatched on April 27, 1937, at which time the fry were approximately 9 mm. long.

‡ This fish was probably missed on May 26 and November 9, when only a random sample of fish was measured.

14 inches early in their second summer, according to Dr. W. C. Beckman (unpublished report, Institute for Fisheries Research). As shown in Figure 4, the small fish remained smaller than average and the large fish larger than the mean until the end of the second summer, when the growth of both groups leveled off, to fall far below the average for the species during the third year. The basis of comparison, the curve of growth in natural waters, is taken from Van Engel's extensive data (1940) for the pike of Wisconsin, which grow at about the same rate as the pike in Michigan, as determined by Beckman. Because the time at which the annulus forms on the scales of Wisconsin fishes has not been determined it has been assumed (Fig. 4) that the time of the formation of the annulus in Michigan is the same as that for Wisconsin. In Michigan Beckman (1943) determined that the formation of the annulus may be expected to be completed by the first of June (average for the entire state), except in unusually cold years.

The depressed growth of the adult pike in the rearing pond during the third year of life may be attributed to the space factor (the Drayton Plains Hatchery was stocked at the rate of 320 northern pike per acre). It is thought that, despite the presence of large quantities of food, northern pike will grow very little in rearing ponds after they have attained a certain size. This species appears to require large bodies of water in order to reach large size.

The growth of the small and the large pike at the Drayton Plains Hatchery furnished an experimental demonstration of the principle of "growth compensation." This term was proposed by Gilbert (1914), who found that salmon (*Oncorhynchus nerka*) which were large at the end of the second year of life grew in succeeding years more slowly on the average than the fish that were small at the end of the second year. Eventually all individuals reached a nearly uniform length at maturity. Van Oosten (1929) determined that the law of growth compensation holds for the lake herring (*Leucichthys artedii*), but although the lengths of the small fish and the large fish became more uniform in each succeeding year of life (the smallest yearlings became the fastest-growing fish and the largest yearlings the slowest-growing fish), the length of the smallest fish did not quite come to equal that of the large fish in later years. Hubbs (1921; 1921a) and Hile (1936) also found that fish which grew more slowly than usual in early life compensated for the de-

iciency by growing faster in later life. There is a large body of other data to indicate that the growth potential of animals is not readily destroyed by a stunting of the early growth.

It is obvious that the small fish grew faster in the Drayton Plains Hatchery than the medium- and large-sized fish did (Figs. 2-5), but, when the pond was drained on October 17, 1939, the small fish had almost caught up with the medium-sized ones, whereas the growth in length of the medium-sized ones paralleled that of the large fish. The rapid growth that was made by the small pike, particularly during their second summer, is a striking example of the great growth potential possessed by the northern pike. Although the differences in the lengths of the three groups diminished during each of the two years, the small fish never quite attained the size of the large fish (Figs. 4-5). The increments in length of each of the three groups of northern pike during each growth period between sampling dates shows that the small fish were the fastest-growing fish and the large fish were the slowest-growing (Table III). This table also shows that these small northern pike were not "genetic runts." Although the small fish got off to a bad start in their first summer, when they were given the proper conditions they were able during the next two years to overcome very largely the effects of the unfavorable conditions to which they were subjected in their first summer of life.

#### SUMMARY

A tremendous spread in length developed early in the season in northern pike reared in hatchery ponds, and this great divergence increased as the summer advanced. Many of the pike grew rapidly and quite variably, but others grew very little and formed a compact-sized group. The growth of the northern pike in rearing ponds follows the pattern of other highly predaceous fishes in pond culture.

The extremely rapid growth of some of the northern pike in rearing ponds is an example of the great growth potential possessed by fishes. The largest fish at the end of the first summer had grown at an average rate of 2.6 mm. and 2.69 grams per day.

The tremendous growth made by some of the northern pike during their first summer was not maintained throughout their retention in rearing ponds for two additional years. It is believed that northern pike will grow very little in such ponds after having attained a certain size.



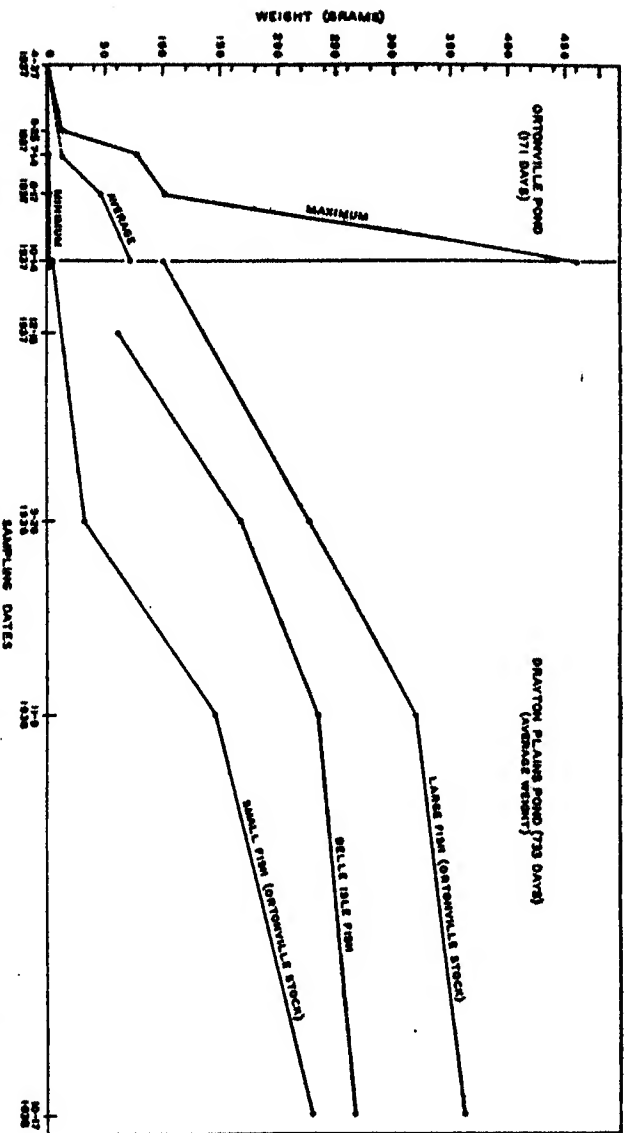


FIG. 3. Growth in weight of the northern pike in rearing ponds at Otonville and Drayton Plains

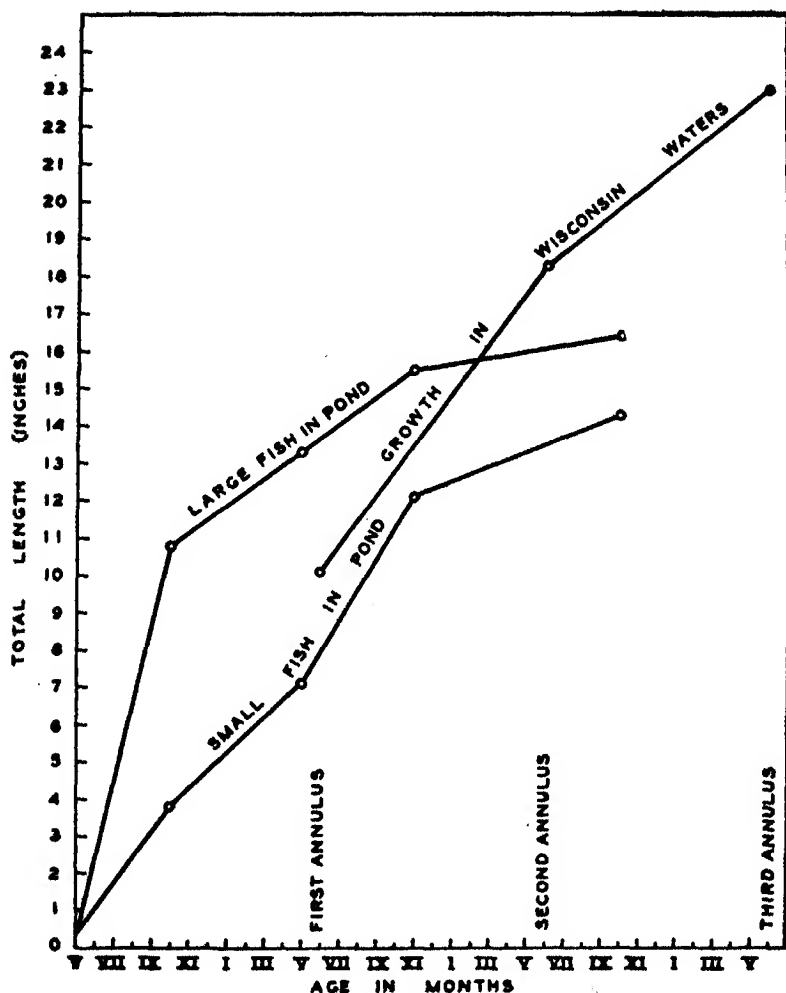


FIG. 4. Growth of small and large northern pike in rearing ponds and the average calculated growth of the species in natural waters

The growth of the northern pike in rearing ponds furnished an experimental demonstration of the principle of growth compensation. The smallest fish at the end of the first year became the fastest-growing fish in succeeding years, and the largest became the

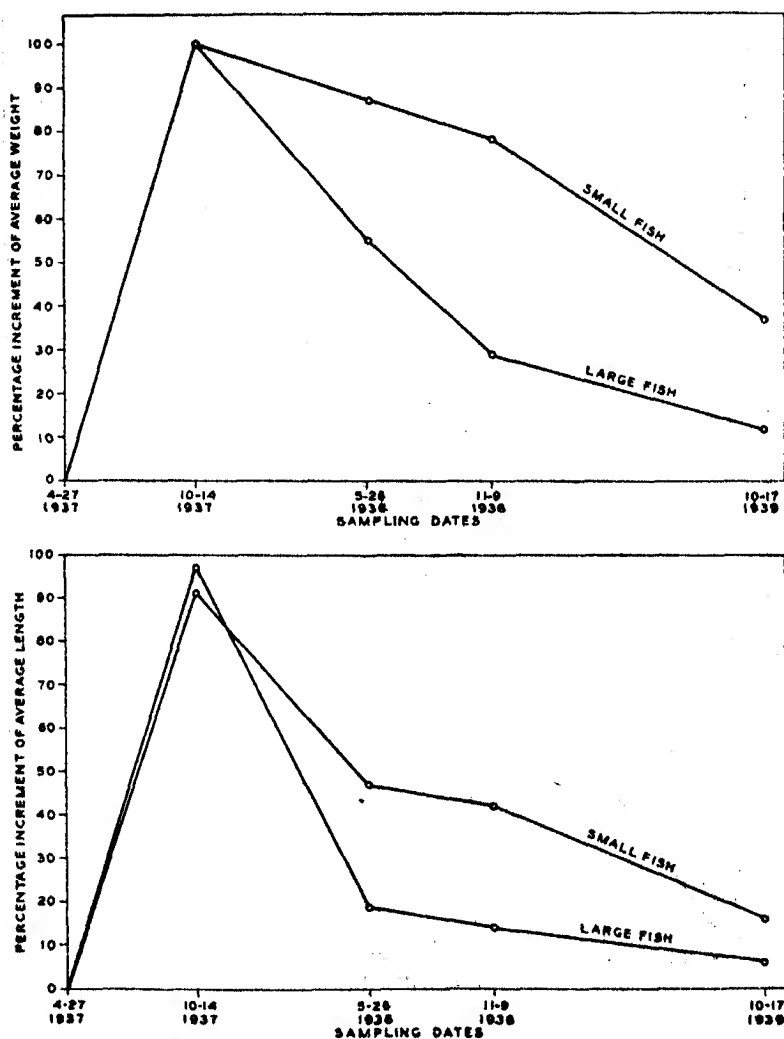


FIG. 5. Percentage increments of the average weight and average length of small and large northern pike in rearing ponds at Ortonville and Drayton Plains

TABLE III

THE AVERAGE INCREMENT OF LENGTH AND WEIGHT AT EACH COLLECTION DATE FOR THE THREE SIZE GROUPS OF NORTHERN PIKE REARED AT THE DRAYTON PLAINS HATCHERY

| Size group           | Length of fish at hatching (mm.) | Average increment in length (mm.)   |              |              |               | Average total length Oct. 17, 1939 |        |
|----------------------|----------------------------------|-------------------------------------|--------------|--------------|---------------|------------------------------------|--------|
|                      |                                  | Oct. 14, 1937                       | May 26, 1938 | Nov. 9, 1938 | Oct. 17, 1939 | Mm.                                | Inches |
| Small fish.....      | 9.0                              | 86.6                                | 84.1         | 127.5        | 56.6          | 363.8                              | 14.3   |
| Belle Isle fish..... | 9.0                              | 236.2*                              | 56.4         | 54.9         | 27.8          | 384.3                              | 15.1   |
| Large fish.....      | 9.0                              | 265.1                               | 65.0         | 54.9         | 23.1          | 417.1                              | 16.4   |
|                      |                                  | Average increment in weight (grams) |              |              |               | Average weight Oct. 17, 1939       |        |
| Size group           |                                  | Oct. 14, 1937                       | May 26, 1938 | Nov. 9, 1938 | Oct. 17, 1939 | Grams                              | Ounces |
| Small fish.....      |                                  | 4.1                                 | 27.5         | 113.6        | 84.8          | 230.0                              | 8.1    |
| Belle Isle fish..... |                                  | 61.9*                               | 106.5        | 65.6         | 33.3          | 267.3                              | 9.4    |
| Large fish.....      |                                  | 101.3                               | 128.2        | 91.7         | 42.5          | 361.7                              | 12.8   |

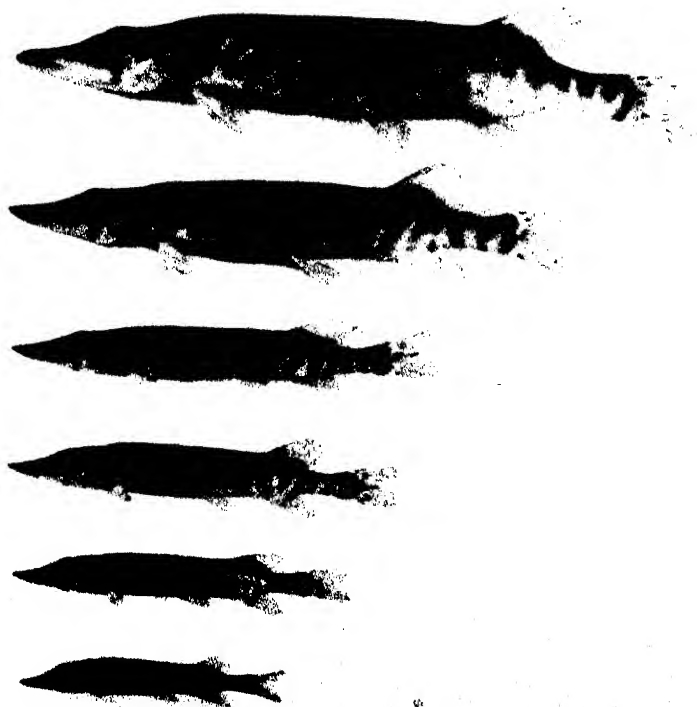
\* The average weight and average length of the Belle Isle fish are for December 15, 1937, the date that these fish were placed in the rearing pond.

slowest-growing. The rapid growth that is made by these small fish is another striking example of the growth potential of the northern pike.

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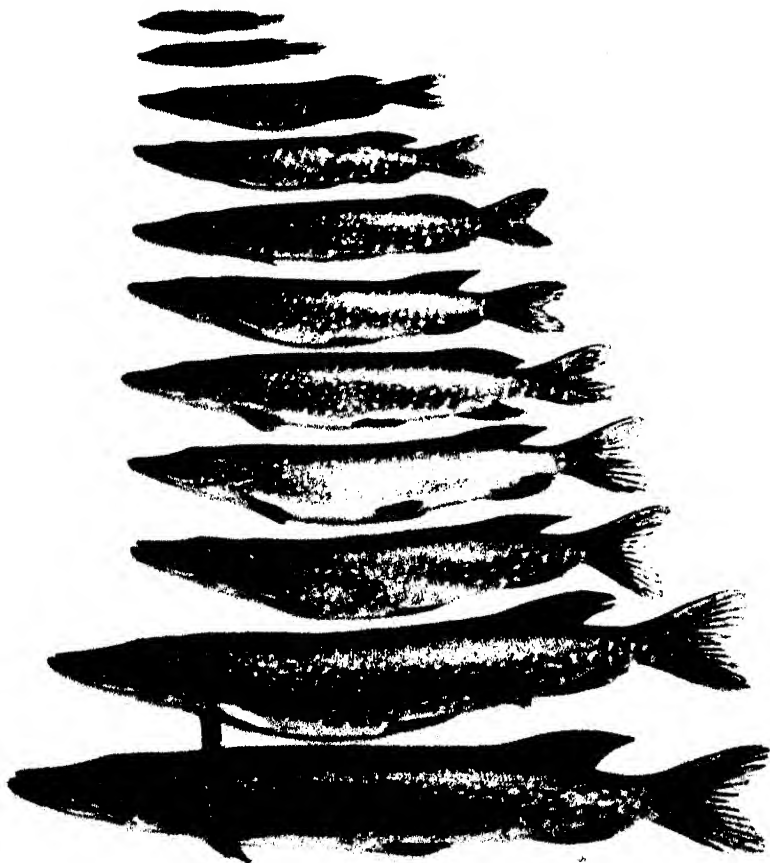
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Group photograph of northern pike collected at the Ortonville Rearing Pond on June 25, 1937. These fish range in size from 50 to 135 mm.





Group photograph of northern pike collected at the Ortonville Rearing Pond on October 14, 1937. These fish range in size from 83 to 446 mm.





THE GREEN HALICTINE BEES OF THE  
GENERA *AGAPOSTEMON*, *AUGOCHLORA*,  
*AUGOCHLORELLA*, AND *AUGOCHLO-*  
*ROPSIS* (HYMENOPTERA: APOIDEA)  
IN MICHIGAN, WITH KEYS  
AND DISTRIBUTION

ROBERT R. DREISBACH

THE bees of the genera *Agapostemon*, *Augochlora*, *Augochlorella*, and *Augochloropsis* are easily identified by their metallic-green or blue-green color. Except in the genus *Agapostemon* both the males and the females have the head, thorax, and abdomen concolorous. In the genus *Agapostemon* the females, with few exceptions, are colored likewise, whereas in the males and a few females the head and thorax are in some shade of green, but the abdomen is marked by yellow and black crossbands. These bees are of about the same color as the Chrysididae or cuckoo wasps, from which they may be separated by the presence of only three or four visible abdominal tergites, by the concave ventral segments, by the concave front below the antennae, and by the absence of branched hairs in Chrysididae. As usual in the Hymenoptera, the males have seven abdominal tergites and thirteen antennal segments; the females have only six and twelve, respectively.

Miss Grace Sandhouse has monographed this group in two papers (1, 2). Her keys for the genus *Agapostemon* can be used for the Michigan species, although at present only four of the eight species and one variety of the genus have been collected in this state. The one variety and three of the other four species may be found in Michigan at some later date. Only one species of the genus *Augochlora* has been recorded from Michigan, and no other is likely to be found. Of the four species of *Augochlorella* one is very common in Michigan, and there is a doubtful record of a second, which most certainly will be collected here, since it is recorded from the neighboring states of Illinois and Indiana.

The key for the genus *Augochloropsis* as given by Miss Sandhouse contains two species for the United States. There are four species and a variety in the writer's collection, and apparently there are at least five species and three varieties in the United States. *Augochloropsis cuprea* (Sm.) has a strong fringe of hairs on the first and second abdominal tergites, whereas *A. viridula* Sm. has only a weak fringe laterally, which is almost wholly absent in the center. She noticed this, but thought of the hairs as having been worn off and mentioned that, where the hairs have been lost, there is a row of tiny punctures. These two species have other and just as great differences that clearly distinguish them. They were considered one species by Miss Sandhouse. There is a third species of this genus which should be found in Michigan since it has been collected in South Dakota. This species is *A. humeralis* (Patton), the *A. caerulea* (Ash.) of Miss Sandhouse. Patton's name should be used since it antedates the other and is not preoccupied.

The writer wishes to thank Dr. P. H. Timberlake, of the Citrus Experiment Station, Riverdale, California, for his determination and checking of species, and also for his suggestions and help in the synonymy and keys in the genus *Augochloropsis*.

#### KEY FOR THE SEPARATION OF THE GENERA

1. Posterior tibiae about equal to length of tarsal joints; female: hind tibiae with knee plate absent, and inner calcar pectinate, with three to five very broad spatulate teeth; head, thorax, and abdomen concolorous with some shade of bright green, except in three species and a variety in which abdomen is black or brown; legs brown or yellowish brown; male: head and thorax blue green, abdomen transversely banded with black and yellow; posterior femur usually much thickened and distinctly thicker than trochanter, toothed below near apex; legs yellow, variously marked with black ..... *Agapostemon*
1. Posterior tibiae about equal to first tarsal joint only; female: hind tibiae with knee plate present, inner calcar pectinate or serrulate, pectinations narrow, pointed; head, thorax, and abdomen concolorous; some part of legs green, the amount depending upon the species; male: head, thorax, and abdomen concolorous with some shade of green; posterior femur neither thickened nor toothed; legs green and black, with tarsi in some specimens yellow ..... 2
2. Pubescence uniformly of one kind and directed posteriorly; tegula large and greenish; posterior tibiae of female with inner calcar with narrow acute pectinations; carinae on lateral margins of propodeum extending almost to dorsal surface; male: tergites beyond third partially retracted within the third; fourth sternite concealed under the third and

- with long posterior lateral processes; margin of fifth emarginate; posterior margin of fourth with median projection; labrum with median basal groove ..... *Augochloropsis*
2. Pubescence consisting of long and short hairs, the long hairs pointing posteriorly and the short ones laterally; carinae on lateral margins of propodeum extending less than halfway to dorsal surface; posterior tibiae of female serrulate with many fine, short serrulations; tegula smaller, brown or testaceous; male: tergites beyond third not retracted within the third; fourth sternite not concealed under the third and without long posterior lateral processes; margin of fifth truncate, that of fourth either truncate or emarginate ..... 3
3. Apex of radial cell slightly truncate, with appendiculation; head broad, ocellocular line longer than postocellar; first sternite of female with median carina or toothed, sixth with median polished area; posterior margin of fourth sternite of male truncate ..... *Augochlora*
3. Apex of radial cell acute without appendiculation; head narrow, ocellocular line equal to postocellar; first sternite of female without carina or tooth, and sixth without median polished area; posterior margin of fourth sternite of male emarginate ..... *Augochlorella*

## KEY TO THE GENUS AGAPOSTEMON

(Based largely on the paper by Miss Sandhouse. Species marked with an asterisk have not yet been found in Michigan.)

1. Females, six abdominal tergites and twelve antennal joints ..... 2
1. Males, seven abdominal tergites and thirteen antennal joints ..... 8
2. Head, thorax, and abdomen concolorous ..... 3
2. Head and thorax green, abdomen brown or black ..... 6
3. Mesonotum of thorax with punctures of one size and nearly contiguous ..... 4
3. Mesonotum of thorax with punctures of two sizes and not contiguous .. 5
4. Mesonotum more finely and uniformly punctured, space between punctures smooth; dorsal surface of propodeum with irregular carinae, appearance dull ..... *A. splendens* (Lepel.)
4. Mesonotum more coarsely punctured, space between punctures rough; dorsal surface of propodeum with regular longitudinal carinae, appearance shining ..... *A. radiatus* (Say)
5. Mesonotum with punctures separated by about their diameter; dorsal surface of propodeum irregularly carinate and usually with distinct triangular area; pubescence tinged with yellow; about 12 mm. in length ..... *A. lezanus* Cress.
5. Mesonotum with punctures separated by about twice their diameter; dorsal surface of propodeum with regular longitudinal carinae; pubescence white, about 10 mm. in length ..... *A. angelicus* (Ckll.) \*
6. Broad basal band of white hair on first abdominal tergite; apex of clypeus black and yellow; abdominal tergites brown or black but tinged with brown or blue-green apically; hair on posterior part of tergites white; wing veins honey yellow ..... 7
6. Two patches of white hair only on lateral sides of first abdominal tergite; apex of clypeus black; abdominal tergites black, not tinged with blue

- green apically; hair on posterior part of tergites black; wing veins light brown ..... *A. virescens* (Fab.)
7. Scape dark brown; apex of abdomen tinged with blue green; apical margin of clypeus black, yellow not extending upward in the middle  
*A. melliventris* var. *plurifasciatus* (Vachal.) \*
7. Scape yellow; apex of abdomen brown; apical margin of clypeus yellow, yellow extending upward to form triangle ..... *A. melliventris* Cress. \*
8. Dark bands on middle tergites about one third length of tergite; base of first tergite generally of brownish tint but never black; femur, tibia, tarsi yellowish except for brownish spot at apex of posterior femur and one at base of posterior tibia; posterior femur scarcely wider than trochanter, the tooth very weakly developed ..... 9
8. Dark bands on middle tergites about one half length of tergite; base of first tergite black; femur, tibia, and tarsi yellowish, but more heavily marked with black; posterior femur very distinctly wider than trochanter, the tooth strongly developed; wings infumated ..... 10
9. Dark bands on abdominal tergites not reaching lateral margins; scape entirely yellow, or with small brownish dot on upper side; trochanters of front and middle legs yellow, those of hind legs tinged with green.  
*A. melliventris* Cress. \*
9. Dark bands on abdominal tergites reaching lateral margins; scape with upper side brown; trochanters of all legs green  
*A. melliventris* var. *plurifasciatus* (Vachal.) \*
10. Apical abdominal tergites, laterally, strongly tinged with metallic blue green ..... 11
10. Apical abdominal tergites dull black, without metallic tints ..... 12
11. Dorsal surface of propodeum with distinct triangle in middle; front and middle trochanters black or black and yellow, if entirely black, then bases of femur are marked with black; posterior tibia always with long black mark on anterior surface, but posterior surface may or may not be similarly marked ..... *A. lezanus* Cress.
11. Dorsal surface without distinct triangle in middle; all trochanters black, but without black on bases of femur; posterior surface of hind tibia with long black mark, but never with one on anterior surface  
*A. angelicus* Ckll. \*
12. Posterior femur strongly swollen, its width distinctly more than one half its length ..... 13
12. Posterior femur not so strongly swollen, its width distinctly less than one half its length ..... *A. splendens* (Lepel.)
13. Species about 9 mm. long; dorsal surface of propodeum with mainly longitudinal carinae, although there are some cross or irregular carinae; abdominal sternites more than half yellow; apical margins of fourth sternite with median green spot; front and middle trochanters and bases of corresponding femur yellow ..... *A. radiatus* (Say)
13. Species about 11 mm. long; dorsal surface with irregular carinae without any tendency to be longitudinal; abdominal sternites black; apical margin of fourth sternite without median green spot; all trochanters black, and bases of femur also marked with black  
*A. virescens* (Fab.)

KEY TO THE GENUS *AUGOCHLORELLA*

1. Sides of propodeum with vertical striations; color blue green to purplish tints; posterior vertical face of propodeum nearly smooth; legs lighter brown, especially posterior femur, which shows less of a metallic tint ..... *A. neglectula* Ckll.
1. Sides of propodeum with striations crossing and forming large cells (reticulate); color bright green to coppery green; posterior vertical face of propodeum rougher, with faint indications of transverse striations; legs darker, especially the posterior femur, which shows a darker shade and more of a metallic tint ..... *A. striata* (Prov.)

KEY TO THE GENUS *AUGOCHLOROPSIS*

1. Pronotal carina with angles sharp and prominent; supraclypeal area uniformly convex and punctured; tergites of abdomen tessellate and dullish; sides of propodeum, above, closely reticulately punctured; sternites brown to yellowish, may be faint greenish tints on two and three ..... *A. humeralis* (Patton) \*
1. Pronotal carina with the angles rounded and not so prominent; supraclypeal area flattened, shining, and sparsely punctured; tergites of abdomen scarcely or not at all tessellate and shining; sides of propodeum, above, closely but hardly reticulate-punctured; sternites two, three, and four greenish ..... 2
2. Tergites one and two with dense fulvous apical fringe; abdominal tergites one and two rather densely and conspicuously punctured; tergites three and four with smooth broad apical edge with deep purple color ..... *A. cuprea* (Sm.)
2. Tergites one and two with apical fringe all but absent, present as very sparse and short fringe laterally; tergites one and two with punctures finer and less conspicuous; tergites three and four with smooth broad apical edge of same color as remainder of tergite, namely, green ..... *A. viridula* Sm.

The distributional records listed below are based on the collections at the University of Michigan and Michigan State College, and the private collection of the writer.

Of the eight species of these genera recorded for Michigan three have been taken in the Upper Peninsula and one other should be found there. All the species have been found in the Lower Peninsula. With the exception of *Augochloropsis viridula* Sm. and *Augochlorella neglectula* Ckll. the species seem to be reasonably common throughout their range.

## ANNOTATED LIST OF SPECIES IN MICHIGAN

**AGAPOSTEMON RADIATUS** Say. — Dates of capture: May 23 to October 3. U. P.:<sup>1</sup> Gogebic. L. P.: Cheboygan, Leelanau, Benzie, Manistee, Lake, Osceola, Clare, Gladwin, Arenac, Mecosta, Isabella, Midland, Bay, Huron, Montcalm, Gratiot, Saginaw, Sanilac, Lapeer, Ingham, Oakland, Calhoun, Washtenaw, Wayne, Berrien, Branch.

**AGAPOSTEMON SPLENDENS**. — Dates of capture: June 3 to September 20. L. P.: Emmet, Cheboygan, Alcona, Manistee, Missaukee Roscommon, Lake, Clare, Arenac, Oceana, Isabella, Nawaygo, Mecosta, Midland, Huron, Muskegon, Gratiot, Saginaw, Lapeer, Ingham, Oakland, Washtenaw, Berrien.

**AGAPOSTEMON TEXANUS** Cress. — Dates of capture: May 24 to September 13. L. P.: Alcona, Missaukee, Oceana, Midland, Lapeer, Oakland, Washtenaw, Wayne.

**AGAPOSTEMON VIRESCENS** Fabr. — Dates of capture: May 30 to September 20. L. P.: Cheboygan, Clare, Nawaygo, Midland, Gratiot, Saginaw, Tuscola, Eaton, Livingston (George Reserve), Oakland, Calhoun, Washtenaw, Wayne, Hillsdale.

**AUGOCHLORA PURA** (Say). — Dates of capture, May 25 to August 27. U. P.: Ontonagon, Baraga, Gogebic, Dickinson, Alger, Mackinac. L. P.: Cheboygan, Charlevoix, Grand Traverse, Manistee, Mason, Mecosta, Midland, Huron, Lapeer, Ingham, Oakland, Van Buren, Washtenaw, Wayne.

**AUGOCHLORELLA NEGLECTULA** Ckll. (*A. aurata* (Sm.), comb. nov. of *Miss Sandhouse*). — L. P.: Elmdale, Michigan (Kent Co.?). This collection is given by E. S. G. Titus (3, p. 134) under the name *A. similis* Robt.

**AUGOCHLORELLA STRIATA** (Prov.). — Dates of capture: April 26 to September 3. U. P.: Marquette, Mackinac. L. P.: Emmet, Cheboygan, Antrim, Otsego, Montmorency, Benzie, Crawford, Missaukee, Roscommon, Ogemaw, Iosco, Mason, Lake, Clare, Gladwin, Arenac, Oceana, Nawaygo, Mecosta, Isabella, Midland, Bay, Huron, Muskegon, Montcalm, Gratiot, Saginaw, Tuscola, Sanilac, Shiawassee, Genesee, Lapeer, Eaton, Livingston (George Reserve), Oakland, Kalamazoo, Washtenaw, Wayne, Berrien.

<sup>1</sup> U. P., Upper Peninsula; L. P., Lower Peninsula.

*AUGOCHLOROPSIS CUPREA* (Sm.). — Date of capture: Aug. 2, 1944.  
L. P.: Muskegon.

*AUGOCHLOROPSIS VIRIDULA* Sm. — Dates of capture: July 24 to August 9. L. P.: Oscoda, Lake, Livingston (George Reserve), Kalamazoo.

MIDLAND, MICHIGAN

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# BILATERAL ASYMMETRY AND BILATERAL VARIATION IN FISHES \*

CARL L. HUBBS AND LAURA C. HUBBS

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\* The parts of this paper dealing with asymmetries in Asiatic fishes result from field explorations and laboratory studies that were supported by research grants from the University of Michigan. The Laboratory of Vertebrate Biology of this university has contributed to the cost of publication.

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## INTRODUCTION

ONE ordinarily sees in bilaterally symmetrical animals creatures composed of identical halves, each a mirror image of the other. Closer scrutiny, however, discloses some degree of asymmetry in many of the paired structures. The differences between the two sides usually involve the internal organs, but also affect certain superficial structures, as well as reactions and movements. Bilateral unlikenesses may be rare, common, unusual, or invariable. When the sides are different, the better development may occur on the left side or on the right side, or sometimes on the left and sometimes on the right, in any conceivable ratio. The differences between the sides may involve the presence or the absence of a structure, the size or the shape of paired elements, or the number of meristic parts. Asymmetries are known to characterize all stages of development, from the unfertilized egg to the dying adult.

Fishes, like all other vertebrates, exhibit such differences between the corresponding structures of the left and right sides. Many bilateral dissimilarities have been treated. The numerous scattered contributions are most adequately summarized in a book, *Das Rechts-Links-Problem im Tierreich und beim Menschen*, by Wilhelm Ludwig (1932). Most of the recorded asymmetries, however, have been inadequately described or unsatisfactorily explained.

The objects of this study are to present new data on the bilateral differences between the left and the right elements of paired structures of fishes; to integrate these findings with previously recorded information; to analyze new and old data by modern statistical methods; to contribute suggestions that may help to explain the observed differences; to give a general picture of the asymmetries; to discuss the bearing of these findings and interpretations on the question of right-handedness in man, and on problems in such fields of biology as general systematics and evolution; and

to offer suggestions for further researches on the bilateral asymmetries of fishes.

Particular attention is paid to the flatfishes (order Heterosomata), the most extremely asymmetrical of all vertebrates. Bilateral differences in external characters are emphasized. The major asymmetries in the digestive and circulatory systems are in general neglected, as they are well known and were extensively summarized, for vertebrates in general and for fishes, by Ludwig (1932: 224-237, figs. 109-110). Similarly, only incidental consideration is given to asymmetries in the egg and in the embryo, and to bilateral differences in growth and movements. Numerical differences are the most thoroughly analyzed, according to methods that call for some explanation.

#### STATISTICAL METHODS

The chief attempt to develop a statistical method for the analysis of quantitative bilateral asymmetries appears to have been made by the German zoologist and biometrician Georg Duncker (1904), in a treatise entitled "Symmetrie und Asymmetrie bei bilateren Thieren." Duncker's statistical methods were reviewed and accepted by Ludwig (1932: 4-8).

Duncker (1904: 555) proposed an index of asymmetry, designated  $\alpha$ , with the following formula:

$$\alpha = \frac{\Sigma(f') \cdot \Sigma(D') - \Sigma(f) \cdot \Sigma(D)}{n[\Sigma(D') + \Sigma(D)]},$$

in which the differences are all expressed in terms of right count minus left count, and

$f'$  = frequencies of positive differences, without regard to amount of difference;

$D'$  = positive differences ( $f' \times \Delta$ ); for example, when the counts of parts are 13 on the right and 10 on the left,  $f' = 1$  and  $D' = 3$ ;

$f$ , = frequencies of negative differences;

$D$ , = negative differences; for example, counts of 10 on the right and 13 on the left give  $f$ , = 1 and  $D$ , = 3;

$n$  = number of specimens. Symmetrical counts (as 10 left and 10 right) are included in  $n$ , but are otherwise disregarded in the formula.

It can be shown that the index of asymmetry has one of the

desirable features of the coefficient of correlation in that complete asymmetry is represented by an index of + 1 when the stronger development is on the right, and of - 1 when the left side is the better developed. Complete symmetry is indicated by 0.

The formula for  $\alpha$  was derived by empirical trial. How sound it may be as a joint measure of the amount and direction of asymmetry we do not know. We have avoided the use of the formula because we see no way of estimating the standard error of the index and, more particularly, because it does not fit our purposes. It is true that Ludwig fixed an  $\alpha$  value of about 0.05 as the threshold of significance, but apparently by unwarranted, arbitrary choice.

Our main objection to the use of Duncker's index is that it confuses two functions of asymmetry — amount and direction. When the proportion of asymmetry is low, the value of  $\alpha$  will be low even though among the few asymmetrical individuals the rights may strongly predominate over the lefts, or vice versa. Thus, for a sample in which every one of the 100 variants out of 10,000 specimens has a higher count on the right side,  $\alpha = 0.01$ , though the significance of the direction of asymmetry — among the asymmetrical individuals, of course — is unquestionable. In a second series in which, out of a total of 100 specimens, 50 have the count greater on the right side and 40 have a higher number on the left,  $\alpha = 0.1$  — a value far above Ludwig's limit of significance. For the first sample the value of  $\alpha$  is one tenth as great as in the second series, yet the direction of asymmetry is much more definite and almost infinitely more significant.

We have separated the two functions of asymmetry. The *amount* of overall asymmetry is expressed as a percentage figure,

$$\frac{100 (L + R)}{N},$$

in which  $L$  and  $R$  represent counts that are higher or development that is otherwise better (on some indicated basis) on the left and right sides, respectively, and  $N$  is the total number of specimens, symmetrical plus asymmetrical, in the sample. The values for  $N$ ,  $L$ , and  $R$  are tabulated. Since we are only incidentally interested in the amount of asymmetry, we have not tried to determine the standard error of the percentage of asymmetry.

The *direction* of asymmetry in the portion of the sample having

different values on the two sides is expressed in the tables by the percentage of dextrality,

$$\frac{100 R}{L + R},$$

in which  $L$  and  $R$  have values as indicated above. The reliability of observed differences between the sides is determined from the values for  $L$  and  $R$  by the now widely used  $\chi^2$  test, and the Yates correction is applied when the expected number (the median between the  $L$  and  $R$  values) is less than 25. The method is described in most textbooks of statistics, for instance, in Snedecor (1940: 168-171) and Simpson and Roe (1939: 296-300).

The probability ( $P$ ) that the ratio of lefts and rights differs from one of equality, in other words, that the result could have been obtained by chance alone, is generally given. In the tables a percentage figure ( $100 P$ ) is entered, indicating the probabilities in 100 that the results are due to chance. The  $100 P$  values are expressed as whole numbers (chances in 100), or to tenths (1 to 9 chances in 1,000), or to hundredths, from 0.01 to 0.09 (1 to 9 chances in 10,000). The  $100 P$  values of 0.00 indicate values of less than 0.005; that is, probabilities of less than 1 in 20,000 that the results are due to chance. Too strict reliance on these  $P$  values is unwarranted, for several statistical reasons, but, relatively speaking, they are valuable as an index of the reliability of the observed differences. The naive faith of biologists in a definite threshold of reliability, at  $P = 0.01$  or  $P = 0.05$ , is to be condemned and avoided. Much higher values afford some evidence of significance, to the degree of reliability indicated by the value of  $P$ .

The tables in textbooks give only a few corresponding values of  $\chi^2$  and  $P$ , but, since in the simple comparison of two figures or in "2  $\times$  2 tables"  $\chi^2$  has one degree of freedom, and since  $\chi$  at one degree of freedom equals  $t$  with an infinite degree of freedom, one needs merely to read off the  $P$  value corresponding to  $\chi = t$ , at 0 skewness, in the newer tables (Salvosa, 1930: tables, pp. 1-60; Carver, 1940: 1-61; Lowan, 1942). It needs be noticed that Salvosa's table, repeated by Carver, gives half of the area of the Type III curve, whereas the "W. P. A. table" (edited by Lowan) gives the whole area. To arrive at the  $P$  value the figures in either table are to be subtracted from 1, but the differences obtained from the use of Salvosa's table are to be multiplied by 2.

## DEXTRALITY AND SINISTRALITY IN FLATFISHES

When one thinks of left-handedness and right-handedness in fishes, his thoughts are apt to turn first to the fishes of the order Heterosomata, in which, during the metamorphosis, one eye shifts to the top of the head, or, more commonly, to the opposite side, so that either the left or the right side comes to bear both of the eyes, leaving the other half of the body blind. During the transformation many asymmetries develop: to a greater or a lesser degree, depending on the genus and species, the anterior part of the skull becomes twisted; the muscular development is more or less weakened on the blind side; the teeth in many species become reduced in number or even totally lost on the eyed side; the color disappears from the blind side; and other inequalities appear. The general morphological nature of the asymmetry is well known (for discussion and references see Norman, 1934: 10-22) and the adaptational advantage is obvious, but the reasons why some species lie on the left side, others on the right side, and still others on either side remain unexplained. The problem warrants new study.

The two species of the genus *Psettodes*, constituting the very primitive family Psettodidae, are the only flatfishes which are indiscriminately sinistral (with both eyes on the left side) or dextral (eyes right), on a basis which can be interpreted plausibly as primordial (Regan, 1910: 488). The optic chiasma in this genus is dimorphic (with either left or right nerve the upper one), as it is in fishes in general (p. 285), and left-eyed and right-eyed individuals are said to occur with about equal frequency. We know of no adequate published data on the laterality of this genus. Some authors have described *P. erumei* as dextral, others as sinistral, and there has even been some discussion as to whether the right-eyed and left-eyed individuals represent a single species. Oshima (1927: 178) listed five sinistral specimens and one dextral from Formosa. The five collected by Carl L. Hubbs at Batavia, Java, in 1929, include two that are sinistral; three, dextral. Twelve specimens from the Philippine Islands and from Batavia, Java, and Hong Kong, China, kindly loaned us by Dr. Leonard P. Schultz of the United States National Museum, comprise three sinistral and nine dextral. The total tally for *P. erumei* (entered in Table I) is therefore ten sinistral and thirteen dextral.

A small group of flounders related to *Citharus* comprises three sinistral genera hitherto placed in the Bothidae and two dextral genera previously classed in the Pleuronectidae (Hubbs, *In press*). In the left-eyed species the nerve of the right eye is dorsal in the chiasma; in the right-eyed forms, the left nerve is superior. There seems to be some obligatory relation between laterality and type of chiasma in this group, for the one known reversed specimen, the dextral individual of *Citharoides macrolepidotus*, referred to below, has the nerve of the left eye dorsal, as it is in the species that are normally dextral. It is suspected that the flounders of the sinistral family Scopthalmidae may show the same relation between the side bearing the eyes and the mode of crossing of the optic nerves.

All flatfishes comprising the four major families are interpreted as normally either dextral or sinistral, whether they be soles (Cynoglossidae and Soleidae), which, though highly specialized in other respects, retain the primitive dimorphic type of chiasma, or flounders and their allies (Bothidae and Pleuronectidae), which have developed a monomorphic chiasma. In all bothids in which the character has been studied the right nerve has always been found to cross dorsally to the left nerve, and the eyes are almost invariably on the left side, whereas in all pleuronectids examined, with the exception of one specimen (pp. 245-246), the left optic nerve has been determined to be dorsal in the decussation, and the eyes and color are normally on the right side. These significant relations between the side bearing the eyes and the type of optic chiasma were discovered by Williams (1902: 34), and were then thoroughly demonstrated in a classical study by Parker (1903). Parker's conclusions have been widely quoted, as by Jordan (1905, 2: 482-483) and Ludwig (1932: 234-237). His results have been extended and confirmed by other workers, including Regan (1910: 487-488), Mayhoff (1912), Wu (1932: 46-47), Norman (1984: 28-29, fig. 19), and Hubbs and Marini (1939: 159-160). The data have been summarized by Gudger (1935: 26-35, fig. 5) and Hubbs (*In press*).

Since the location of the eyes is almost invariable in the respective families, the tongue soles (Cynoglossidae) are regarded as normally sinistral; the true soles (Soleidae), as normally dextral. Because of the almost constant position of the eyes in most species, and because of the correlation between the location of the eyes and the



special type of monomorphic chiasma, the turbot (Bothidae) are regarded as normally sinistral; the flounders proper (Pleuronectidae), as characteristically dextral. Specimens with the eyes on the side that is normally blind are said to be reversed. This condition is regarded as abnormal, even for those species or races which often have the eyes on the "wrong" side, including the invariably reversed Asiatic races of one species.

#### REVERSAL OF SIDES IN FLOUNDERS

Extensive reviews of the problem of reversal in flounders (Ludwig, 1932: 234-237; Norman, 1934: 27-29, *et passim*; Gudger, 1935; Hubbs and Kuronuma, 1943: 298-301) have shown: (1) that sinistral Soleidae are exceedingly rare and that dextral Cynoglossidae are still unknown; (2) that dextrality occurs with extreme rarity in all bothids, except in a very few Pacific species which are said to be indifferently sinistral or dextral; and (3) that sinistrality is so rare as to appear teratological in all Pleuronectidae, except the two species now referred to *Platichthys* and possibly also the North Pacific species *Hippoglossoides elassodon* and the New Zealand genus *Rhombosolea*. Our study proves that *Hippoglossoides elassodon* is now to be removed from the list (pp. 237-238). Adequate data on the proportion of rights and lefts in *Rhombosolea* are not available.

In the European flounder, now known as *Platichthys flesus*, the percentage of reversal varies widely, but usually remains below 50 per cent, as demonstrated by Duncker (1895: 82-83; 1900: 339-340), Berg (1932: 3-7), Ludwig (1932: 235), Norman (1934: 28), and Gudger (1935: 20, 29-30). Geographical variation in laterality that is even more remarkable is exhibited by the Pacific species *P. stellatus*, in which the percentage of reversal is 49 to 60 in western North America, 68 about Kodiak Island and the Alaska Peninsula, and 100 in Japan (Hubbs and Kuronuma, 1942: 298-301). Since the data for *Platichthys stellatus* are now very extensive, the differences in percentage of reversal between the species of *Platichthys* are certainly not related, as Gudger (1935: 21) thought that they might be, to the size of the commercial catch.

The reversal of sides in the Japanese population of *Platichthys stellatus* seems to be invariable or at least nearly constant, for all the 476 Japanese specimens examined were sinistral. Hybrids between this sinistral *Platichthys* and the dextral species *Kareius bi-*

*coloratus* were both sinistral (14) and dextral (13). These data furnish some of the strongest evidence that reversal is genetically determined.

As the foregoing account shows, reversal is a common phenomenon only in Pacific species and in *Platichthys flesus* of Europe. Jordan and Goss (1889: 230-233, 242-245), Jordan and Evermann (1898: 2602-2712), Parker (1903: 231), Jordan (1905, 2: 481-483, 492), and Regan (1910: 487) were impressed by the indiscriminate laterality of several flounders along the west coast of the United States. The high frequency of reversal in the flounders of the northeastern Pacific can be explained in part only by the greater development in that region of the groups concerned, namely, the Paralichthyinae and the Pleuronectidae (see zoogeographic analysis by Norman, 1934: 48-50). It may, of course, be only a series of coincidences (1) that the Pacific species of *Platichthys* is reversed more often than the Atlantic form; (2) that the only species of *Paralichthys* reported to have both eyes commonly on the right side is *P. californicus*; and (3) that among the genera related to *Paralichthys* only eastern Pacific representatives, *Hippoglossina* and *Xystreurus*, are reported to be indiscriminately sinistral or dextral. The almost complete restriction to the Pacific Ocean of the species with aberrant laterality still poses a problem.

Except for *Platichthys stellatus* no statistical data of consequence have been reported on the percentage of reversal among the Pacific species which are claimed to be more or less indiscriminately right-sided or left-sided. Parker's (1903: 231-232) figures of 11 sinistral (normal) and 15 dextral (reversed) examples of *Paralichthys californicus*, as well as those of 50 dextral (normal) and 50 sinistral (reversed) specimens of *Platichthys stellatus*, though repeated by Ludwig (1932: 235-236) and by Gudger (1935: 19-21), probably represented selected samples. Extensive series of counts are called for to determine how "indiscriminate" the sidedness is in the variable Pacific species. A small number of counts are contributed toward this need in Table I. The data for *Psettolodes erumei* are discussed on page 234. The data for *Tephrinectes sinensis* are those of Oshima (1927: 193), who reported 4 sinistral and 3 dextral specimens from Formosa, and of Wu (1932: 47, fig. 17) who recorded 2 sinistral and 4 dextral examples from China; plus one dextral specimen from Canton, China. *Paralichthys californicus* is almost surely nor-

TABLE I

DATA ON SIDE BEARING EYES IN PACIFIC FLATFISHES REPORTED TO BE MORE OR LESS INDISCRIMINATELY SINISTRAL OR DEXTRAL

Based on material in the Museum of Zoology of the University of Michigan (except as noted in the text). The limited data on *Platichthys stellatus* are a slight supplement to the more than 18,000 counts for this species published by Hubbs and Kuronuma (1942: 299-300). None of the material was selected for sidedness.

| Family (and normal condition)     | Species and locality                                                                            | Number of specimens |         |
|-----------------------------------|-------------------------------------------------------------------------------------------------|---------------------|---------|
|                                   |                                                                                                 | Sinistral           | Dextral |
| Psettodidae (indiscriminate)      | <i>Psettodes erumei</i> , Philippines, Java, and China .....                                    | 10                  | 13      |
| Bothidae (normally sinistral)     | <i>Tephrinectes sinensis</i> , Formosa and China .....                                          | 6                   | 8       |
|                                   | <i>Hippoglossina stomata</i> , southern California .....                                        | 3                   | 0       |
|                                   | <i>Paralichthys californicus</i> , southern California .....                                    | 93                  | 57      |
|                                   | <i>Xystreurus liolepis</i> , southern California .....                                          | 9                   | 18      |
|                                   | <i>Hippoglossoides classodon</i> , Frederick Sound, Alaska (shrimp trawls, Sept. 1, 1939) ..... | 0                   | 312     |
| Pleuronectidae (normally dextral) | Other localities, Alaska and Puget Sound .....                                                  | 0                   | 16      |
|                                   | <i>Platichthys stellatus</i> , California .....                                                 | 13                  | 18      |

mal oftener than reversed; our counts, yielding a *P* value of 0.003, are 93 sinistral and 57 dextral (part of the material is in the California Academy of Sciences). It is possible that *Xystreurus liolepis*, by contrast, may be more commonly reversed than normal, for the ratio in the material at hand is 9 sinistral to 18 dextral. The allocation of *Xystreurus* in the Bothidae is not to be questioned, for the right optic nerve is the more dorsal (Hubbs and Marini, 1939: 159). Frequent variation in the side bearing the eyes is thus confirmed for all species just mentioned. We find no basis and no confirmation, however, for the statements that *Hippoglossoides classodon* is "sometimes" or "frequently" sinistral (Jordan and Gilbert, 1883: 826, 827; Jordan and Goss, 1889: 230; Jordan and

Evermann, 1898: 2605, 2615). If reversal does occur in this species, it must be with rare frequency. The three specimens of *Hippoglossina stomata* listed are all sinistral, as was a specimen recorded previously (Hubbs, 1916: 168). More data on this genus are greatly needed, since the statements in the literature (Jordan and Goss, 1889: 230, 242; Jordan and Evermann, 1898: 2620; Norman, 1934: 28, 65) are based on very limited material and are somewhat conflicting.

Variability in the location of the eyes is, for some unknown reason, much less common in the northwestern than in the northeastern Pacific. In his elaborate doctoral study of Japanese flounders and soles, based on the extensive collections which Carl L. Hubbs made in 1929, Katsuzo Kuroshima determined, among the hundred species occurring in Japan: (1) that supposedly indiscriminate laterality characterizes only *Psettodes erumei* and *Tephrosetes sinensis*, which barely reach the waters of Japan proper and are unrepresented in the collections made there in 1929; (2) that *Platichthys stellatus* (as already stated) is invariably reversed in Japan; (3) that out of nearly 2,400 specimens, representing the other Japanese species, only two are reversed. The ratio of 1:1,200 for reversed: normal individuals of these ninety-seven species may be too high, for the Japanese collectors from whom the specimens were received in 1929 may have preserved both of these reversed flatfish because of their abnormality. One is a dextral example of *Citharoides macrolepidotus*, one of the two Japanese examples at hand of this citharid (Hubbs, *In press*). The other one is the unique sinistral representative (Pl. I, Fig. 2) found among the 201 specimens of the pleuronectid species *Tanakius kitaharae* collected in 1929. The only other known cases of reversal among the flounders of eastern Asia are: (1) a dextral specimen of *Paralichthys olivaceus*, with the right optic nerve dorsal (Wu, 1932: 47), (2) a dextral example of the bothid species *Pseudorhombus pentophthalmus* (Kamohara, 1935: 682, fig. 6), and (3) a sinistral *Limandella yokohamae*, with the left optic nerve superior (Wu, 1932: 47). The reversed specimens recorded by Wu were found in an extensive study of Chinese flatfishes.

The discovery of occasional reversal in five additional species, just mentioned, strengthens the opinion that all species of flounders may occasionally have the eyes and color on the side which is

normally blind and white. Why the phenomenon of reversal is frequent in only a few species remains a total enigma.

#### DECREASED VIABILITY OF REVERSED FLOUNDERS

There is some evidence that sinistral individuals of normally dextral flounders (*Platichthys*) are less viable than the right-handed ones. Published statements to this effect are based on the following data for *Platichthys flesus* of Europe (Duncker, 1900: 339-340):

. . . Apstein<sup>1</sup> fand unter 154 jungen (3,5—8,4 cm langen) Tieren aus der Eckernförder Bucht 56 (= 36,4 %), ich<sup>2</sup> unter 90 gleichfalls jungen (1,9—6,6 cm langen) aus der Neustädter Bucht 31 (= 34,4 %) linksäugige; unter 225 marktreifen<sup>3</sup> Stücken aus der westlichen Ostsee und von der Nähe der Elbmündung erhielt ich dagegen nur 53 (= 23,6 %) linksäugige, sodass der Prozentsatz der letzteren bei den jungen Tieren höher war. Dementsprechend finde ich auch bei dem Plymouth-Material in den drei kleineren der sechs unterschiedenen Grössengruppen linksäugige Exemplare etwas häufiger, als in den drei grösseren (geschlechtsreifen) und zwar bei beiden Geschlechtern in dem nahezu gleichen Verhältnis 1:0,85 ( $\sigma^7 = 7,14:6,12$  %,  $\varphi = 4,20:3,52$  %). Unter 192 metamorphosierenden Larven von Megavissey-Harbor waren nur 11 (= 5,73 %) linksäugige, also nicht mehr, als unter dem noch nicht geschlechtsreifen Teil des Materials.

Da eine nachträgliche Veränderung der Augenstellung bei den Plattfischen ausgeschlossen ist, so lässt sich nur auf eine höhere Sterblichkeit der linksäugigen Exemplare gegen die Geschlechtsreife hin schliessen.<sup>4</sup> Ob der von mir gefundene Unterschied der Geschlechter in der Augenstellung — nahezu 1½ mal soviel linksäugige Männchen, wie Weibchen — ein durchgreifender ist, muss einstweilen dahingestellt bleiben.

Duncker's conclusion that the percentage of sinistrality decreases with age in the flounder of the Baltic Sea seems to be statistically valid, provided the results were not greatly affected by local or temporal variation. The ratio of lefts to rights in the young was 87:157; in the adults, 53:172. The  $\chi^2$  value for the difference between these ratios is 8.18, corresponding to a *P* value of 0.004; that is, there are only 4 chances in 1,000 that the differences in the ratios would have been caused by chance.

Duncker's evidence was confusingly presented by Gudger (1935:

<sup>1</sup> *Mith. deutsch. Seefischereiver.*, 1894, No. 5.

<sup>2</sup> *Ibid.*, 1897, No. 1.

<sup>3</sup> Ich verstehe unter „marktreif“ Tiere von ca. 20 cm Länge und darüber.

<sup>4</sup> Vielleicht ist eine Erfahrung erwähnenswert, die ich kürzlich (Ende Mai 99) mit 67 jungen (1,5—3 cm langen) Elbbutt machte. Für das Aquarium gefangen, erlitten diese 67 Tiere einen längeren Transport in demselben Gefäss unter gleichen Bedingungen; es kamen lebend an 14 links- und 31 rechtsäugige; es gingen unterwegs ein 11 links- und 11 rechtsäugige.

22-23, 29). Apparently misled by the title of Apstein's paper, Gudger attributed to the plaice (*Pleuronectes platessa*) Apstein's figures (1894: 106) on the percentage of sinistrality in young flounders (*P. flesus*). These were the data utilized by Duncker in the passage just quoted, and they apply without doubt to the flounder. Assuming that they refer to the plaice, Gudger was confronted by a seemingly enormous decrease with age in the number of reversed individuals in that species. To explain the change he postulated an almost complete mortality of the young plaice, but, of course, no amount of nonselective mortality would affect the proportion of reversed to normal individuals. There is no reason to think that young plaice are reversed except with the extreme rarity that characterizes this phenomenon in most flatfishes. Similarly, confirming the statements by Williams (1902: 34) and Parker (1903: 230), we find no reversed individuals among more than one hundred transformed young of the related species, the winter flounder, *Pseudopleuronectes americanus americanus* (these specimens, from Massachusetts, grade down to 11 mm. in standard length).

Confirmatory though not fully conclusive evidence on the decreased viability of reversed flounders was kindly furnished us by the late Dr. E. Victor Smith, of the University of Washington (Table II). His extensive data appear to show that the Puget Sound form of the starry flounder, a race of *Platichthys stellatus rugosus*, is slightly oftener sinistral (reversed) when young than when adult. Unfortunately the most acceptable comparison, between the 1928 and 1929 adults and the 1930 and 1931 fish, largely young, both from Boundary Bay, does not yield a statistically reliable result: the ratios of sinistral to dextral fish are 444:475 and 254:234, respectively; the  $\chi^2$  value for the difference in ratios is 1.78, corresponding to a  $P$  value of 0.18. A rather highly trustworthy difference exists between the ratios for the Boundary Bay adults (445:475) and for the fish, very largely young, taken in the same year about the San Juan Islands (3,436:3,151):  $\chi^2 = 4.79$  and  $P = 0.03$ . One cannot exclude with full confidence, however, the possibility that racial, annual, or seasonal variations were responsible for the observed differences. The data in Table II are a breakdown of figures summarized by Hubbs and Kuronuma (1942: 300). Other counts of normal and reversed individuals of *Platichthys stellatus* published by these authors are too diverse for locality, or too uniform or too

TABLE II

RELATION BETWEEN AGE AND SINISTRALITY IN *PLATICHTHYS STELLATUS*  
FROM PUGET SOUND

The data were kindly furnished by the late Dr. E. Victor Smith, of the University of Washington. Localities are as follows: (1) San Juan Islands; (2) Boundary Bay; (3) Seattle. More specific data on age are not at hand.

| Age                                                             | Locality | Year | Number of specimens examined | Percentage reversed (sinistral) | Median |
|-----------------------------------------------------------------|----------|------|------------------------------|---------------------------------|--------|
| Very large majority in first year                               | 1        | 1928 | 1,687                        | 52.22                           | 52.18  |
|                                                                 | 1        | 1929 | 4,900                        | 52.14                           |        |
| Largely in first year, with a few scattered through older years | 2        | 1930 | 277                          | 52.71                           | 51.95  |
|                                                                 | 2        | 1931 | 211                          | 51.18                           |        |
| Mostly small, but more large fish than in preceding series      | 3        | 1929 | 422                          | 50.47                           | 50.47  |
|                                                                 | 3        | 1930 |                              |                                 |        |
| All large, none less than two years old                         | 2        | 1928 | 318                          | 49.69                           | 48.64  |
|                                                                 | 2        | 1929 | 601                          | 47.59                           |        |

indefinite as to age, to bear significantly on the problem of present concern.

The dextral individuals of *Platichthys*, normal in the sense that dextrality is almost universal in the Pleuronectidae, seem to have a slightly better chance than the sinistral ones to reach maturity. It is difficult, but not impossible, to reconcile this interpretation with the evidence (Hubbs and Kuronuma, 1942: 298-301) that laterality is inherited in *Platichthys stellatus*, that reversal has remained close to 50 per cent on the American west coast for decades, and that reversal is invariable in Japan. Further and more detailed data on the proportion of left-eyed to right-eyed individuals in the young of the starry flounder, particularly in recently transformed young, are still a great desideratum, as Gudger (1935: 21-22) wrote. So far as possible, in such studies efforts should be made to eliminate the factors of racial, annual, and seasonal variation, which were not completely excluded in the accumulation of the data discussed above.

The supposedly decreased viability of reversed flounders has been cited by Parker (1903: 229-238), Mayhoff (1912: 84-85), Norman

(1934: 28), and others as evidence that the monomorphic chiasma arose as a product of selection. The extreme twisting of the optic nerves in reversed bothids and pleuronectids has been stressed by Parker and subsequent workers as a mechanical disadvantage; the monomorphic chiasma of the Bothidae and the Pleuronectidae is interpreted as allowing a simple and direct ontogeny. The dorsal location of the nerve of the migrating eye in both groups leads in the normal (unreversed) individuals to a partial uncrossing rather than a double crossing of the optic nerves. Such adaptations toward direct development are frequent — whatever the evolutionary mechanism may be. But if sinistrality in the Bothidae and dextrality in the Pleuronectidae arose because these conditions have a selectional advantage, why has reversal of sides become common in several species of Bothidae and in both species of *Platichthys*? In particular, we may well ask, Why has *Platichthys stellatus* become invariably reversed in eastern Asia?

Whatever may be its evolutionary basis, reversal of sides in the flounder families with a monomorphic chiasma is surely to be regarded as a secondary development (Parker, 1903: 234; Norman, 1934: 28). Ambilaterality is obviously both primitive and common only in the Psettodidae, and presumably remains primitive, though it has become rare in the Soleidae and also in the Citharidae and probably in the Scophthalmidae (Hubbs, *In press*).

#### INCOMPLETE MIRROR IMAGING IN REVERSED FLOUNDERS

One of the most remarkable features of variation in the side of flounders bearing the eyes is the lack of complete mirror imaging (the one completely reversed specimen described on pp. 245-246 provides an exception to this statement and to each of the following generalisations in this section). On superficial examination dextral and sinistral examples of the same species do appear to be mirror images, and indeed they were commonly so regarded prior to 1903, but closer inspection has shown that certain structures exhibit no reversal. Thus, as already pointed out (p. 235), it has been demonstrated adequately that the right optic nerve is invariably dorsal in all Bothidae and that the left nerve is dorsal in all Pleuronectidae, without respect to the side bearing the eyes. The monomorphic asymmetry is established prior to metamorphosis (Williams, 1902: 34; Parker, 1903: 230; Jordan, 1905, 1: 174).



That the viscera in the flatfishes constantly maintain the bilaterally asymmetrical arrangement that is characteristic of fishes in general, with the liver on the left side and the intestinal coils against the right body wall, has already been determined (Cunningham and MacMunn, 1894: 801; Cunningham, 1907: 176; Norman, 1934: 29). I have verified this conclusion by an examination of numerous flounders, including both dextral and sinistral specimens of: (1) *Psettodes erumei*, a species of the Psettodidae, in which neither side can be said to be normal, neither reversed; (2) *Citharoides macrolepidotus*, one of the ordinarily sinistral species of the Citharidae; (3) *Paralichthys californicus* and *Xystreurus hiolepis*, members of the normally sinistral family Bothidae; and (4) *Platichthys stellatus*, representing the normally dextral Pleuronectidae. The typical pattern of asymmetry holds for both dextral and sinistral individuals of *P. stellatus* on the American west coast and for the exclusively sinistral Japanese race; also for the dextral and sinistral hybrids between *Kareius bicoloratus* and *Platichthys stellatus*. Hubbs and Kuronuma (1942: 295-298) obviously drew up their description of the visceral anatomy of these species and the hybrids from sinistral specimens and wrongly indicated that this pattern holds also for the dextral hybrids and *Kareius*; for those forms the term "blind side" in the published account should have read "right side" or "eyed side." It is obvious that the more fundamental features of visceral asymmetry are fixed prior to metamorphosis, in the pattern that is characteristic of fishes in general.

There is at least one other bilateral asymmetry in certain flatfishes that maintains a constant pattern unrelated to the general twisting of the head and body. In representative specimens of the few flatfishes in which these folds remain separate, instead of being symmetrically conjoined (Schmidt, 1915: 442-443; Hubbs, *In press*), we find that the right branchiostegal membrane embraces the urohyal and is covered by the more deeply pigmented left membrane. This is true of *Psettodes erumei* and of *Citharoides macrolepidotus*, whether the specimen be dextral or sinistral in respect to eyes and color. The left membrane also overlaps the right in another sinistral citharid, *Citharus macrolepidotus*, as well as in the dextral citharid *Brachypleura novae-zeelandiae*. The left membrane is also constantly the outer one in *Lophopsetta aquosa* and other Scophthalmidae, of which only sinistral specimens are known. We

conclude that this asymmetry in the folding of the gill membranes must be established very early in the life of these flatfishes, prior to metamorphosis. In fact, the pattern was established very early in the evolution of modern fishes: the left membrane overlaps the right in *Amia calva*, and this condition is more or less definitely retained throughout the teleost series (Hubbs, 1920:62, see also pp. 278-280 of the present paper).

#### A COMPLETELY REVERSED FLATFISH

An exception to the rule that there is no complete reversal of bilateral parts in flounders is furnished by the one known sinistral example (Pl. I, Fig. 2) of *Tanakius kitaharae* (Jordan and Starks), a Japanese species of the normally dextral Pleuronectidae (Pl. I, Fig. 1). This specimen, already referred to (pp. 235, 239), is an adult 220 mm. in standard length. It was collected in the Pacific Ocean off Onahama, Japan, by the Fukushima-ken Fishery Experiment Station, and was presented to Carl L. Hubbs in Japan in 1929.

In all essential respects this sinistral example seems to be the mirror image of a normal *Tanakius*. The intestine projects into the backward extension of the coelome on the left side, rather than on the right side, as it normally does in this and several other genera, without any hitherto known exception. The liver is on the right side, rather than on the left, as it is in all other flatfishes so far as previously determined, whether they be dextral or sinistral. The intestinal coils are on the left side, rather than the right, as in all other known specimens. This is the general rule for fishes. *Situs inversus viscerum* is presumably rare among the Pisces, although Lynn (1943) recorded an incidence of 4.7 per cent among 510 single embryos of trout and a higher percentage among conjoined twins. Ludwig (1932:379) quoted data on *situs inversus* in amphibians, but not in fishes.

Suspecting that this fish might represent a complete reversal, we examined the crossing of the optic nerves. The right nerve was found to pass dorsally to the left nerve, a position never recorded in a pleuronectid, either normal or reversed. The optic nerves cross but once, instead of twice, as they do in all other known reversed flounders, with one exception, whether they be referable to the Pleuronectidae or to the Bothidae (Hubbs, *In press*). In this

respect the reversed. *Tanakius* agrees with the reversed (dextral) *Citharoides*, but that fish (p. 235) retains the normal asymmetry of viscera and of branchiostegal membranes. The appearance is that of a sinistral specimen of the typically sinistral Bothidae, as represented by Parker's often reproduced figure 5 (1903) or by Mayhoff's figure 3 (1912), rather than that of a reversed example of the normally dextral Pleuronectidae. It seems certain, however, that this specimen is not a bothid, for it is obviously a reversed individual, and all its characters stamp it as an aberrant member of the pleuronectid species *Tanakius kitaharae*.

This specimen provides the first known exception to the rule that the optic chiasma is invariably monomorphic in the Bothidae and Pleuronectidae. It furnishes the first known case, for either family, of the mirror imaging of the chiasma. That the left optic nerve is normally the more dorsal in *Tanakius kitaharae* was demonstrated by the dissection of ten dextral specimens.

In the more usually observed asymmetrical characters this specimen is also reversed. The blind side is nearly colorless and is less muscular than the ocular side. The urinary papilla is on the eyed surface. The head parts are just the reverse of normal.

In two other respects the completely reversed *Tanakius* specimen is slightly teratological. The posterior end of the dorsal fin is somewhat deflected onto the blind side, instead of retaining, as usual, a position along the median dorsal line. On the eyed side of the abdomen, an isolated segment of the lateral line, with well-developed pored scales, extends upward for some distance from between the pelvic fin and the anus.

It seems obvious that reversal is more fundamental in this specimen than in any other known flatfish.

#### INTERPRETATION OF REVERSAL IN FLATFISHES

A reversed symmetry of the early embryo or egg — involving some embryonic structure or position, the direction of cell cleavage, or the constitution of the egg itself — probably accounts for the complete change-over of right and left elements in the specimen just described, but seems not to be involved in the ordinary reversal of sides in the Heterosomata. No other specimen of flatfish is known to have all its organs reversed. Usually in two and sometimes in three characters reversed flatfishes are not perfect mirror images

of normal specimens. The asymmetries of the optic chiasma in the Bothidae and the Pleuronectidae, of the viscera in all flatfishes, and of the gill membranes in several genera (pp. 243-245), obviously become established in a pattern which is unrelated to the later twisting of the head. These almost invariable asymmetries must be fixed very early in development, for certain flatfishes metamorphose at a small size (data on the size at transformation were summarized by Norman, 1934:30-33). The types and degree of asymmetry seem to bear little relation to the size at which one eye migrates to the opposite side of the head. Some flatfishes, particularly the tropical Bothidae, transform at a surprisingly large size. The record case is that of *Laeops parviceps*, of which there has been described a postlarva 70.5 mm. in standard length, with one eye still on each side of the head (Hubbs and Chu, 1934:3-6, pl. 2).

The one completely transformed specimen of *Tanakius* is, therefore, the only reversed flatfish that is fundamentally comparable to sinistrally coiled snails. Reversal in the Gastropoda has been traced to a 180° change in the direction of cell cleavage. The literature on reversal of coiling in gastropods was reviewed at length by Ludwig (1932:159-191, figs. 103-105).

Sinistrality in normally dextral flounders and dextrality in those that belong to the sinistral groups are no more related to situs inversus of the viscera in flatfishes than left-handedness is associated with situs inversus in man.

A number of authors, including Cunningham (1907:175-176), Gudger (1935:35), and Hubbs and Kuronuma (1942:301), have concluded that laterality, whether normal, reversed, or variable, is genetic. The facts of the case (p. 237) lead very strongly to this conclusion. The production of rights and lefts in approximately equal numbers, in the hybrids derived from the natural crossing of the dextral species *Kareius bicoloratus* and the invariably sinistral Japanese races of *Platichthys stellatus* (Hubbs and Kuronuma, 1942:300), suggests strongly that simple genetic factors are involved in determining whether a flounder be left-eyed or right-eyed. There is no evidence that cytoplasmic inheritance is operative in the development of flatfish asymmetry.

From the viewpoints both of bionomics and of developmental mechanics many theories have been advanced to explain why some

flatfishes lie on the left side, others on the right. Involved theories have been published, by Ludwig (1942:237), for example, to explain how unilaterality became established and how reversal has taken place. Lamarekian factors have been stressed by many of the theorists. None of the hypotheses proposed has met with any general acceptance (Norman, 1934:13, 31). Most of the attempted explanations have some unacceptable or unprovable basis. As a whole, these proposals have transcended factual information and have merely added confusion to a difficult puzzle.

The one interpretation that has been generally agreed upon, since Parker's work was published in 1903, is that reversal is a secondary and not a primary feature, except in *Psettodes*. This conclusion seems to be warranted both for the soles, which retain the primitive dimorphic chiasma, and for the Bothidae and Pleuronectidae, which have a monomorphic decussation of the optic nerves. It may be questioned for the members of the small families Citharidae and Scopthalmidae (Hubbs, *In press*).

Whether or not reversed flounders are to be regarded as teratological depends in part on the point of view (Gudger, 1935). It has been noted, however, that reversal of the sides often occurs in flounders that have other abnormalities, such as ambicoloration and partial albinism. Gudger (1935) referred to a number of such specimens, including the exceedingly abnormal turbot reported by Cunningham (1907), and has since described three specimens combining reversal with ambicoloration (Gudger, 1936a; Gudger and Firth, 1937). The completely reversed specimen of *Tanakius kitaharae* recorded above shows other anomalies (p. 246). In the New Zealand genus *Rhombosolea* reversal is usually accompanied by the reappearance of the normally lacking pelvic fin of the blind side, according to Norman (1926:278-280; 1934:28-29). In species which are rarely reversed there is apparently some association between reversal of sides and other abnormalities, particularly ambicoloration. Since the coloring of both sides is interpreted as a return toward symmetry (see following section), it may be that this return is often carried beyond the mid-point, so as to lead to a change in the side bearing both eyes. In view of the data given in the next paragraph this is a more plausible idea than that the reversal of the sides leads to ambicoloration.

It seems to be significant, in this connection, that such anomalies

as ambicoloration are apparently no more common in the several North Pacific flounders which are notable for their indiscriminate laterality than they are in species which always or almost always have the eyes and color on one of the sides. None of the reversed specimens listed in Table I showed any sign of ambicoloration or other abnormality. We have heard of only three cases of ambicoloration in *Platichthys stellatus*, the flatfish with the record proportion of reversals, and only one of these reports rests on a specimen, a dextral individual from southeastern Alaska that was described by Gudger (1941). One hearsay record was mentioned by Gudger, and we can now add a third report. Silva, the long-time fisherman of Morro Bay, California, described to us personally what was certainly another ambicolorate *Platichthys*, "the same on both sides." These three teratological individuals are the only ones which have been noticed by men who have handled many thousands of starry flounders. Among the 476 specimens examined of the invariably sinistral Japanese race not one presented any obvious anomaly. There is no reason to think that ambicoloration and other terata are any commoner in *Platichthys stellatus*, which varies geographically from a condition of indiscriminate laterality to one of complete reversal, than they are in flatfish species that are never or virtually never reversed.

#### TERATOLOGICAL RETURN TOWARD SYMMETRY

The teratological condition of flatfishes known as ambicoloration, with related modifications, has been interpreted as a return toward the symmetrical structure of ordinary fishes. Not only the color but also other characters of the eyed side, for example, ctenoid scales, may appear on the eyeless side. The migrating eye may not have rotated the usual distance, and the forward extension of the dorsal fin, which ordinarily follows the transit of the eye, may not have been completed. As a result, a dorsal hook is commonly developed in extreme examples of ambicoloration. The subject was treated at some length, with a review of the literature, by Norman (1934:22-27, figs. 18-19), and more recently has been extensively investigated by Gudger (1935, 1936a, 1936b, 1941; Gudger and Firth, 1935, 1936, 1937).

Although numerous ambicolorate flatfish have been described, the condition must be extremely rare. The aberration is so striking

that it has often come to the attention of zoologists. Numerical data on the relative frequency of ambicoloration have not been published. It may be of interest, therefore, to note that among the 2,412 specimens of Japanese flounders handled by Katsuzo Kuronuma (doctoral thesis, University of Michigan, probably still unpublished), only three were colored on both sides, and these may have been preserved because of their abnormality. Two of the specimens are of *Verasper variegatus*, a species that usually has scattered dark spots on the lower surface. One of the two has the hooked dorsal fin commonly associated with ambicoloration. The other *Verasper* and the one ambicolorate specimen of the abundant species *Limandella yokohamae* have a normal dorsal fin.

#### SECONDARY ASYMMETRIES IN FLATFISHES

Although there are a few basic asymmetries that maintain a left-right gradient unaltered by the reversal of the sides, the majority of the head and body characters develop bilateral dissimilarities along with or following the migration of the eye. Profound differences, for example, arise between the corresponding left and right elements in the skeleton and the musculature. Many of these secondary asymmetries have been described, and efforts have been made to interpret the findings (Norman, 1934: 1-55, figs. 1-28). Some have argued that the migration of the eye directly causes the excessive twisting of the anterior part of the skull; others have regarded the flexure of the skull as the primary movement, which carries the eye along with it. Objections have been raised, however, to any such simple cause-and-result relationship. In modern view it seems much more plausible to assume that a multitude of factors is involved, and that the whole genetic and developmental mechanism is keyed to the production of an organism that is asymmetrical in almost every element of internal and external anatomy.

Next to the unilateral position of the eyes, the bilateral difference in color is the most conspicuous feature in the asymmetry of the Heterosomata. In most flatfishes whichever side is blind is white, and almost entirely devoid of melanophores, whereas the upper side is thoroughly equipped with chromatophores. These color cells expand and contract as the exposed side marvelously simulates the color and the color pattern of the bottom on which the fish lies (references in Norman, 1934: 21).

Not all flatfishes, however, are unpigmented on the lower surface. In the primitive, relatively not greatly asymmetrical species *Psettodes erumei* we note a slight darkening of the under side. Similarly, a gray shade covers this side in the secondarily subsymmetrical flounders, such as *Atheresthes*. One such form first loses, then regains pigment on the under surface (Norman, 1934: 21). Oddly, some of the more or less extremely asymmetrical flounders, such as certain species of *Glyptocephalus*, *Taeniopsetta*, *Engyophrys*, and *Verasper*, develop dark pigment on the blind side, either as a shade or as a pattern of bars or spots. The adult male of *Crossorhombus kobensis*, a Japanese bothid, has a large violet wedge on the lower surface (Hubbs, 1915: 459). The dark spots on the lower surface of the "hogchoker," an American sole, are almost wholly confined to *Trinectes maculatus maculatus*, the northern subspecies (Hubbs and Allen, 1944: 128). Such variations in the pigmentation of the side on which the flatfishes lie are not readily explainable.

Since it was shown by Cunningham (1891, 1893, 1895; Cunningham and MacMunn, 1894) that flatfishes illuminated from below develop pigment on the normally white skin, some have thought that the lack of color is the direct result of the absence of light. Cunningham found, however, that heredity is involved, for in early development the pigment of the illuminated blind side first disappeared, "and it was only later after long exposure to light that pigment developed on the lower side."

In many flounders the lateral line is developed only on the eyed side, or is better developed there. Basic data are a part of the systematic literature (reviewed by Norman, 1934). In the best statistical analysis of this asymmetry Duncker (1900: 374-375, 392; 1904: 576-578, 646-647, 653) demonstrated that the accessory branch of the lateral line of *Platichthys flesus* averages longer on the ocular side than on the blind side. Quantifying the length of the line by listing the number of the dorsal ray opposite which the line ended, Duncker determined for 1,024 dextral specimens that the length was alike on the two sides in 590 fish, greater on the eyed (right) side in 279, and greater on the blind (left) side in only 155. In sinistral (reversed) flounders the degree of asymmetry was approximately the same, but the direction was altered: the accessory lateral line was usually longer on the left surface. In both cases the greater development was on the side that bears the eyes.



The perfection of scale development on the two sides of flounders is another character that is associated in some way with the direction taken by the migrating eye in metamorphosis. Commonly the scales of the upper side are ctenoid, whereas those of the opposite surface are cycloid (see systematic literature, especially Norman, 1934). Again it is not a problem of which side is right or which is left, but, rather, a question of which half of the body bears both eyes and which half has none. That definite hereditary factors are involved is clearly indicated by the manner in which the tubercular scales are developed on the blind side — whether left or right — in *Kareius* × *Platichthys* hybrids (Hubbs and Kuronuma, 1942: 278-287, pl. 4).

An asymmetrical location of either the anus or the urinary papilla, and usually of both these structures, is also correlated with the general somatic asymmetry established at metamorphosis. Schmidt (1915: 444), as quoted by Norman (1934: 19), "has drawn attention to the asymmetrical position of the anal papilla, which in all flatfishes, including those in which the vent is placed on the blind side, is situated on the ocular side of the median line." We have confirmed this finding for numerous species. The only species that we have found to furnish an exception to Schmidt's rule are the primitive flounder *Psettodes erumei*, in which a urogenital papilla lies close to the anus, in the same fossa, slightly on the blind side and in line between the anus and the front of the anal fin, and the members of three American bothid genera (*Citharichthys*, *Etropus*, and *Syacium*), in which both the papilla and the anus are deflected onto the blind side (Hubbs, *In press*). In dealing with *Platichthys flesus* Duncker (1895: 81) pointed out that the papilla is the urogenital opening in the males but only the urinary opening in ripe females, and we observe the same situation in *Tanakius kitaharae*. Duncker found the papilla on the blind side in only one specimen of *P. flesus*, among very many studied, and mentioned that Gottsche made a similar observation on one plaice that was white on both sides. Hubbs (1915) noted that the anus of flatfishes in general either lies on the mid-ventral line or is more or less transposed to the blind side, except in *Citharoides* and *Citharus*. In a thorough survey of this character throughout the pleuronectoid flatfishes Norman (1934) determined, in confirmation, that the anus is usually more or less displaced onto the blind side, and lies definitely on the eyed

side only in the two genera just mentioned. In *Citharoides*, as in its close relative *Citharus*, the urinary papilla arises on the edge of the anal opening on the eyed side of the body (in the reversed fish as well as in the normal specimens at hand); in another citharid, *Brachypleura*, the two organs are also on the eyed side; but are slightly separated (Hubbs, *In press*). In all bothids and in all pleuronectids examined the anus and the urinary papilla are separated from each other by a considerable expanse of body surface.

A test was made of the conclusion that the location of the urinary papilla is consistently correlated with the eyedness or blindness rather than with the sinistrality or dextrality of the sides. In more than two hundred specimens of *Platichthys stellatus*, nearly equally divided between rights and lefts, the papilla was on the eyed side without exception. In all the specimens the anus was on the blind side. Similar findings were obtained on normal and reversed specimens, though in smaller numbers, of *Paralichthys californicus* and of *Xystreureys lolepis*.

Unlike the major features of visceral topography, which early develop a gradient of asymmetry unrelated to that taken by the eyes, the posterior openings of the kidney and the intestine have, therefore, an asymmetry that is quite consistent with that of the eyes and color. Apparently the positions of the urinary papilla and of the anus are among the numerous characters that are fixed subsequent to metamorphosis.

Likewise, in some flatfishes marked asymmetries correlated with the position of the eyes appear in the area of the gill covers; this region may be larger or more posterior or otherwise different on one side than on the other. These differences between the two surfaces are reversed when there is a change-over in the position of the eyes. In this respect the superficial gill-cover structures do not follow the monomorphic asymmetry of the branchiostegal membranes and rays (p. 244), which is obviously established earlier in development.

An interesting asymmetry involving the presence of a bone on one side and its absence on the other is exhibited by *Citharoides macrolepidotus*. In this species the supplementary maxillary bone is developed consistently on the blind side but is lacking on the ocular surface.

In the three genera of the Citharidae examined, namely, *Citharus*, *Citharoides*, and *Brachypleura*, a peculiar asymmetry is evident in

the structure of the pectoral fin rays. In the fin of the eyed side the articulations of the rays are much longer than broad, whereas in the blind-side fin the joints of the rays are much broader than long (Hubbs, *In press*). An approach toward this condition is shown by some other flatfishes, including *Psettodes erumei*.

In almost all flatfishes the paired fins are larger and otherwise better developed on the eyed side than on the blind side — whether the eyed side be left or right, and whether the specimen be normal or reversed in respect to the position of the eyes. The supporting data fill the systematic literature on the Heterosomata (ably reviewed by Norman, 1934). It was concluded by this ichthyologist (p. 20) that the pectorals in some flounders are subequal, and, as an exception to the general rule, we find that *Psettodes* usually has the pectoral fin of the blind side the larger (p. 257). In a number of genera of both flounders and soles the pectoral or pelvic fin of the ocular side may be well developed when its mate of the blind side is rudimentary or totally lacking. In these genera, of course, there is a constant difference in the number of pectoral or pelvic rays on the two sides. Bilateral variation in the number of rays in the paired fins, in species of flatfishes having these fins well developed on both sides, calls for special treatment.

#### BILATERAL VARIATION IN NUMBER OF RAYS IN PAIRED FINS ON THE TWO SIDES OF FLATFISHES

When, as usual, the paired fins of flatfishes are developed on both sides, the fin of the eyed surface as a general rule has on the average a higher number of rays than does the corresponding fin of the blind side — whether the eyes face to the left or to the right. The first and still the most thorough statistical demonstration of this secondary asymmetry was made by Duncker (1897: 819-820; 1900: 356-357, 362; 1904: 630-633; data reviewed by Ludwig, 1932: 6-8). In *Platichthys flesus* Duncker found that in the normal or dextral individuals the right pectoral nearly always contains more rays than the left fin; that the number of pelvic rays when different on the two sides is higher on the right side in the ratio of about 2:1; and that the differences are accentuated, when only the branched rays are enumerated (data reanalyzed in Tables III-IV). In sinistral or reversed individuals the left fin (now on the eyed side) has the higher number of rays; the asymmetry is almost the

TABLE III

AVERAGE NUMBER OF PECTORAL AND PELVIC RAYS ON THE LEFT AND RIGHT SIDES OF DEXTRAL AND SINISTRAL FLOUNDERS (*PLATICHTHYS FLEBUS*)

Based on 1,060 dextral and 60 sinistral specimens, from Plymouth, England; data from Duncker (1900:356). The averages for the right fin are in bold-faced type.

|                           | Eyed side, average | Blind side, average |
|---------------------------|--------------------|---------------------|
| Total pectoral rays       |                    |                     |
| Dextral specimens .....   | <b>10.804</b>      | 10.143              |
| Sinistral specimens ..... | 10.800             | <b>10.217</b>       |
| Branched pectoral rays    |                    |                     |
| Dextral specimens .....   | <b>6.215</b>       | 2.529               |
| Sinistral specimens ..... | 6.373              | <b>2.746</b>        |
| Total pelvic rays         |                    |                     |
| Dextral specimens .....   | <b>5.983</b>       | 5.960               |
| Sinistral specimens ..... | 6.033              | <b>5.950</b>        |
| Branched pelvic rays      |                    |                     |
| Dextral specimens .....   | <b>0.778</b>       | 0.276               |
| Sinistral specimens ..... | 0.800              | <b>0.350</b>        |

same in degree, but reversed in direction. Obviously the correlation is not with the rightness or the leftness of the side but, rather, with eyedness or blindness.

Confirmatory results (Tables IV-V) were obtained in an analysis of the number of pectoral and pelvic rays on the eyed and blind sides of normal and reversed starry flounders, *Platichthys stellatus rugosus*. The counts were all made on specimens collected in the Columbia River mouth, Oregon and Washington, on July 20-21, 1926. The series of 225 specimens comprises 89 normal (dextral) and 136 reversed (sinistral) individuals. Since none of the fish were adult and most were small, the counts were made under a microscope and, when necessary, the skin was cut to make sure that the smallest rudiments were included. The counts of branched rays are valid for the bilateral comparison for specimens of this size, but do not equal the counts that would be obtained from adult fish, since additional rays dichotomize with increasing size. Perhaps in larger fish a significant difference between the eyed and the blind sides might be demonstrated in the number of branched pelvic rays, to conform with Duncker's results on *P. flebus*. There

TABLE IV

ASYMMETRY IN NUMBER OF RAYS, TOTAL AND BRANCHED, IN FLOUNDERS  
OF THE GENUS *PLATICHTHYS*

*L* signifies that the count is higher on the left side; *R*, that the count is higher on the right side.

|                              | <i>N</i> | <i>L</i> | <i>R</i> | $\frac{100 (L + R)}{N}$ | $\frac{100 R}{L + R}$ | 100 <i>P</i> |
|------------------------------|----------|----------|----------|-------------------------|-----------------------|--------------|
| <i>Platichthys flesus</i> *  |          |          |          |                         |                       |              |
| Dextral specimens            |          |          |          |                         |                       |              |
| Pectoral rays                |          |          |          |                         |                       |              |
| Total .....                  | 1,059    | 17       | 661      | 64                      | 97                    | 0.00 †       |
| Branched .....               | 1,014    | 2        | 992      | 98                      | 100                   | 0.00         |
| Pelvic                       |          |          |          |                         |                       |              |
| Total .....                  | 1,056    | 20       | 41       | 6                       | 67                    | 1            |
| Branched .....               | 1,054    | 31       | 425      | 43                      | 93                    | 0.00         |
| <i>Platichthys stellatus</i> |          |          |          |                         |                       |              |
| <i>rugosus</i> ‡             |          |          |          |                         |                       |              |
| Dextral specimens            |          |          |          |                         |                       |              |
| Pectoral rays                |          |          |          |                         |                       |              |
| Total .....                  | 89       | 3        | 40       | 48                      | 93                    | 0.00         |
| Branched .....               | 89       | 0        | 89       | 100                     | 100                   | 0.00         |
| Pelvic rays                  |          |          |          |                         |                       |              |
| Total .....                  | 89       | 2        | 3        | 6                       | 60                    | ...          |
| Branched .....               | 89       | 1        | 1        | 2                       | 50                    | ...          |
| Sinistral specimens          |          |          |          |                         |                       |              |
| Pectoral rays                |          |          |          |                         |                       |              |
| Total .....                  | 136      | 57       | 5        | 46                      | 8                     | 0.00         |
| Branched .....               | 136      | 135      | 0        | 99                      | 0                     | 0.00         |
| Pelvic rays                  |          |          |          |                         |                       |              |
| Total .....                  | 136      | 10       | 3        | 10                      | 23                    | 10           |
| Branched .....               | 136      | 5        | 0        | 4                       | 0                     | 7            |

\* Data from Duncker (1904: 647-648), for specimens from Plymouth, England.

† A 100 *P* value of 0.00 indicates that the odds are less than 1 in 20,000 that the result obtained is due to chance.

‡ Original data, for young specimens from the mouth of the Columbia River, Oregon and Washington, collected July 20-21, 1926.

is a greater difference between the pelvic rays of the two fins than the figures indicate, because in a number of specimens with the same count in the right and the left pelvic the fin of the blind side only has the last ray rudimentary. As in *P. flesus*, the differences in the pectoral ray counts are much greater for the number of branched

TABLE V

DIFFERENCES BETWEEN PECTORAL RAY COUNTS OF THE TWO SIDES IN DEXTRAL AND SINISTRAL SPECIMENS OF *PLATICHTHYS STELLATUS RUGOSUS*

Based on 89 dextral and 136 sinistral specimens collected July 20-21, 1926, in Columbia River mouth.

|                  | Excess of count of eyed side over that of blind side |    |    |   |    |    |    |    |    |    | M    |
|------------------|------------------------------------------------------|----|----|---|----|----|----|----|----|----|------|
|                  | - 1                                                  | 0  | 1  | 2 | 3  | 4  | 5  | 6  | 7  | 8  |      |
| Total rays       |                                                      |    |    |   |    |    |    |    |    |    |      |
| <i>D</i> * ..... | 3                                                    | 46 | 36 | 4 | .. | .. | .. | .. | .. | .. | 0.46 |
| <i>S</i> † ..... | 5                                                    | 74 | 52 | 3 | 1  | 1  | .. | .. | .. | .. | 0.44 |
| Branched rays    |                                                      |    |    |   |    |    |    |    |    |    |      |
| <i>D</i> * ..... | ..                                                   | .. | .. | 4 | 11 | 18 | 17 | 24 | 14 | 1  | 5.03 |
| <i>S</i> † ..... | ..                                                   | 1  | .. | 9 | 16 | 25 | 33 | 34 | 11 | 7  | 4.91 |

\* Dextral (normal) specimens, with the right count (that of eyed side) typically higher than the left count.

† Sinistral (reversed) specimens, with the left count (that of eyed side) typically higher than the right count.

rays than for the total number of rays (Table V). This differential seems to hold for flounders in general, with at least one outstanding exception: in *Xystreurus liolepis* the rays are branched in the pectoral fin of the blind side (either right or left), but remain unbranched in the long straplike pectoral of the ocular side (Hubbs and Marini, 1939:162). The mean difference between the counts of dichotomized rays on the two sides is nearly the same in the dextral and sinistral specimens, showing again that the number of rays is correlated with eyedness or blindness rather than with rightness or leftness.

The conclusion that eyedness of the side is correlated with the differential development of the paired fins among flatfishes in general is verified by systematic descriptions and, more particularly, by a statistical study of the Japanese species (Table VI). The outstanding exception to the rule appears, from this tabulation, to be provided by the most primitive of all the flounders, *Psettodes*, which has a dimorphic optic chiasma and one eye on the top of the head. In *Psettodes erumei* the fin of the blind side seems to have the higher average ray count, almost surely not a lower average. The blind-side fin also averages the larger and the stronger (this is true in four-



|                                     |    |    |    |    |     |     |    |    |    |                            |        |      |
|-------------------------------------|----|----|----|----|-----|-----|----|----|----|----------------------------|--------|------|
| <i>Pseudorhombus cinamomus</i>      | .. | .. | .. | .. | 3   | 22  | 4  | .. | .. | 12.03 ± .09<br>11.41 ± .14 | 3.76   | 0.02 |
| Ocular side                         | .. | .. | .. | .. | 3   | 13  | 1  | .. | .. |                            |        |      |
| Blind side                          | .. | .. | .. | .. | ..  | ..  | .. | .. | .. |                            |        |      |
| <i>Pseudorhombus pentophthalmus</i> | .. | .. | .. | .. | 9   | 106 | 3  | .. | .. | 11.41 ± .04<br>10.12 ± .05 | 21.86  | 0.00 |
| Ocular side                         | .. | .. | .. | .. | 126 | 71  | .. | .. | .. |                            |        |      |
| Blind side                          | .. | .. | .. | .. | ..  | ..  | .. | .. | .. |                            |        |      |
| <i>Tarphops oligolepis</i>          | .. | .. | .. | .. | 33  | 12  | .. | .. | .. | 10.28 ± .08<br>8.87 ± .10  | 10.76  | 0.00 |
| Ocular side                         | .. | .. | .. | .. | 7   | ..  | .. | .. | .. |                            |        |      |
| Blind side                          | .. | .. | .. | .. | ..  | ..  | .. | .. | .. |                            |        |      |
| <i>Arnoglossus tenuis</i>           | .. | .. | .. | .. | 1   | 6   | 1  | .. | .. | 11.46 ± .22<br>8.85 ± .27  | 7.50   | 0.00 |
| Ocular side                         | .. | .. | .. | .. | 4   | ..  | .. | .. | .. |                            |        |      |
| Blind side                          | .. | .. | .. | .. | ..  | ..  | .. | .. | .. |                            |        |      |
| <i>Engrasopom grandisquama</i>      | .. | .. | .. | .. | 4   | 8   | .. | .. | .. | 10.67 ± .14<br>9.08 ± .08  | 9.70   | 0.00 |
| Ocular side                         | .. | .. | .. | .. | ..  | ..  | .. | .. | .. |                            |        |      |
| Blind side                          | .. | .. | .. | .. | 11  | ..  | .. | .. | .. |                            |        |      |
| <i>Crossorhombus kobensis</i>       | .. | .. | .. | .. | 22  | 21  | 2  | .. | .. | 10.46 ± .10<br>9.19 ± .08  | 10.16  | 0.00 |
| Ocular side                         | .. | .. | .. | .. | 12  | ..  | .. | .. | .. |                            |        |      |
| Blind side                          | .. | .. | .. | .. | ..  | ..  | .. | .. | .. |                            |        |      |
| <i>Laepe kikkaruz</i>               | .. | .. | .. | .. | ..  | 5   | 2  | 9  | 1  | 12.92 ± .15<br>11.50 ± .23 | 5.18   | 0.00 |
| Ocular side                         | .. | .. | .. | .. | 1   | ..  | 5  | 1  | .. |                            |        |      |
| Blind side                          | .. | .. | .. | .. | ..  | ..  | .. | .. | .. |                            |        |      |
| <i>Pleuronectidae (dextral)</i>     | .. | .. | .. | .. | ..  | ..  | .. | .. | .. |                            |        |      |
| <i>Atheresthes evermanni</i>        | .. | .. | .. | .. | ..  | ..  | 4  | 5  | 4  | 14.00 ± .23<br>14.17 ± .21 | - 0.06 | 95   |
| Ocular side                         | .. | .. | .. | .. | ..  | ..  | 2  | 6  | 4  |                            |        |      |
| Blind side                          | .. | .. | .. | .. | ..  | ..  | .. | .. | .. |                            |        |      |
| <i>Hippoglossoides dubius</i>       | .. | .. | .. | .. | 9   | 12  | .. | .. | .. | 10.05 ± .07<br>9.73 ± .07  | 3.17   | 0.2  |
| Ocular side                         | .. | .. | .. | .. | 45  | ..  | .. | .. | .. |                            |        |      |
| Blind side                          | .. | .. | .. | .. | 38  | 5   | .. | .. | .. |                            |        |      |
| <i>Clashtenes pinctorum</i>         | .. | .. | .. | .. | 2   | 126 | 75 | 9  | .. | 11.21 ± .05<br>11.04 ± .05 | 2.35   | 2    |
| Ocular side                         | .. | .. | .. | .. | 51  | 121 | 61 | 8  | .. |                            |        |      |
| Blind side                          | .. | .. | .. | .. | 6   | ..  | .. | .. | .. |                            |        |      |



TABLE VI (Concluded)

|                                 | Number of pectoral rays |    |    |    |     |    |    |    |    |                 | $M \pm SE$ | $t$  | 100 P |
|---------------------------------|-------------------------|----|----|----|-----|----|----|----|----|-----------------|------------|------|-------|
|                                 | 7                       | 8  | 9  | 10 | 11  | 12 | 13 | 14 | 15 |                 |            |      |       |
| PLEURONECTIDAE (dextral, Cont.) |                         |    |    |    |     |    |    |    |    |                 |            |      |       |
| <i>Xystias grigorjewi</i>       |                         |    |    |    |     |    |    |    |    |                 |            |      |       |
| Ocular side                     | ..                      | .. | 1  | 30 | 125 | 17 | .. | .. | .. | 10.92 $\pm$ .04 | 0.19       | 85   |       |
| Blind side                      | ..                      | .. | .. | 24 | 136 | 11 | .. | .. | .. | 10.91 $\pm$ .04 |            |      |       |
| <i>Verasper variegatus</i>      |                         |    |    |    |     |    |    |    |    |                 |            |      |       |
| Ocular side                     | ..                      | .. | .. | 2  | 17  | 7  | 1  | .. | .. | 11.26 $\pm$ .13 | - 0.37     | 71   |       |
| Blind side                      | ..                      | .. | .. | 3  | 13  | 10 | 1  | .. | .. | 11.33 $\pm$ .14 |            |      |       |
| <i>Verasper moseri</i>          |                         |    |    |    |     |    |    |    |    |                 |            |      |       |
| Ocular side                     | ..                      | .. | 1  | .. | 1   | 9  | 1  | 2  | .. | 12.07 $\pm$ .32 | 0.21       | 83   |       |
| Blind side                      | ..                      | .. | .. | .. | 1   | 12 | 1  | .. | .. | 12.00 $\pm$ .10 |            |      |       |
| <i>Cleidoderma asperillum</i>   |                         |    |    |    |     |    |    |    |    |                 |            |      |       |
| Ocular side                     | ..                      | .. | .. | .. | ..  | 5  | 7  | 5  | .. | 13.00 $\pm$ .19 | 2.54       | 1    |       |
| Blind side                      | ..                      | .. | .. | .. | 2   | 7  | 8  | .. | .. | 12.35 $\pm$ .17 |            |      |       |
| <i>Pleuronichthys cornutus</i>  |                         |    |    |    |     |    |    |    |    |                 |            |      |       |
| Ocular side                     | ..                      | .. | 13 | 59 | 69  | 7  | .. | .. | .. | 10.47 $\pm$ .06 | 1.29       | 20   |       |
| Blind side                      | ..                      | .. | 16 | 70 | 55  | 7  | .. | .. | .. | 10.36 $\pm$ .06 |            |      |       |
| <i>Lepidopsetta mochipareti</i> |                         |    |    |    |     |    |    |    |    |                 |            |      |       |
| Ocular side                     | ..                      | .. | 1  | 3  | 11  | 18 | 2  | .. | .. | 11.49 $\pm$ .14 | 1.85       | 6    |       |
| Blind side                      | ..                      | .. | 2  | 7  | 13  | 12 | 1  | .. | .. | 11.09 $\pm$ .16 |            |      |       |
| <i>Limanda pinnatifistima</i>   |                         |    |    |    |     |    |    |    |    |                 |            |      |       |
| Ocular side                     | ..                      | .. | 9  | 3  | ..  | .. | .. | .. | .. | 9.25 $\pm$ .13  | 3.38       | 0.1  |       |
| Blind side                      | ..                      | 5  | 7  | .. | ..  | .. | .. | .. | .. | 8.58 $\pm$ .15  |            |      |       |
| <i>Limnodella herzensteini</i>  |                         |    |    |    |     |    |    |    |    |                 |            |      |       |
| Ocular side                     | ..                      | .. | 11 | 55 | 38  | 4  | .. | .. | .. | 10.32 $\pm$ .07 | 4.74       | 0.00 |       |
| Blind side                      | ..                      | 1  | 29 | 63 | 13  | 2  | .. | .. | .. | 9.87 $\pm$ .07  |            |      |       |



teen of the seventeen specimens at hand; in the other three the fin is slightly longer on the eyed side). In *Citharoides macrolepidotus*, another very primitive species (Hubbs, *In press*), the number of rays seems to average as high on the blind as on the eyed side, if, indeed, it is not higher. In this species the fin of the lower surface, though shorter, is broader and has heavier rays than the fin of the upper side.

*Atheresthes*, a pleuronectid genus with the left eye on the dorsal margin, and the only member of the subfamily Pleuronectinae with the primitive type of olfactory lamellae, gives a very slightly but not reliably higher average for the blind (left) side. In *Atheresthes*, which contrasts with *Psettodes* in this respect, the fin of the ocular side is much larger than that of the eyeless side. The number of rays is probably about equal on the two sides in both species of *Verasper* (the average is slightly higher on the eyed side in one species and on the blind side in the other). It is perhaps significant that all the species just mentioned are more or less pigmented on the blind side, which in most flounders is white. A few other species have the averages very close, but the great majority have more rays in the eyed-side pectoral than in the blind-side fin. In the Bothidae the dimorphism in ray number is roughly proportionate to the degree of bodily asymmetry: slight in the most symmetrical genus, *Paralichthys*; somewhat more marked in *Pseudorhombus*; striking in the more asymmetrical genera, such as *Arnoglossus* and *Laeops* (Table VI) and *Chascanopsella* (Kuronuma, 1940:48). Among the Pleuronectidae the dimorphism in numbers is less markedly increased in the most asymmetrical representatives. In the sinistral flounders (Bothidae) the difference between the upper pectoral fin (in this family the left one) and the right pectoral is greater as a rule than that between the right — normally uppermost — and left fins in the dextral group (Pleuronectidae). This asymmetry may be correlated with the probably greater number of rays in the left pectoral fin of the ambidextrous *Psettodes*. In six of the nine bothids tabulated (and also in *Chascanopsella lugubris*) the ray counts of the two pectoral fins are found to differ on the average by more than 1.00 ray; the greatest difference for any of the pleuronectids is 0.67 ray.

As would be expected from the detailed analyses on *Platichthys stellatus*, the invariably sinistral (reversed) Japanese races of this

species have on the average more rays in the left (upper) pectoral than in the fin of the right side. The difference (0.49) is a little greater than the average for the Japanese pleuronectids. About the same difference (0.52) exists between the ray counts of the eyed-side and blind-side pectorals in the *Kareius*  $\times$  *Platichthys* hybrids, which are dextral and sinistral in approximately equal numbers (Hubbs and Kuronuma, 1942: 298-301). The only other reversed specimens treated in Table VI are one each of *Citharoides macrolepidotus* and *Tanakius kitaharae*.

In the cases which have just been cited the number of rays in the pectoral fin, the characteristic which corresponds in the fish most literally to handedness in man, is associated with the general asymmetry of the body. In a somewhat converse relation various bodily asymmetries in the fiddler crabs appear to be correlated with the right or left location of the larger cheliped (Duncker, 1903; 1904: 632-633; Ludwig, 1932: 6-8, 202-210). Such relations give credence to the theories that dominant handedness in man may be related to some other major asymmetry, at some phase of development. There are, however, facts that argue against the validity of various causal relations that have been propounded.

#### ASYMMETRIES AND BILATERAL VARIATIONS IN ESSENTIALLY SYMMETRICAL FISHES

Like vertebrates in general, fishes other than the flounders and the soles appear on superficial examination to be completely symmetrical about the sagittal axis, but closer scrutiny indicates that in many respects the two sides are not perfect mirror images of each other. Dissection discloses that there are many fundamental and almost invariably monomorphic asymmetries in the digestive and circulatory systems. With very rare reversals, either right or left directions are taken or flexures assumed by various embryonic processes. Such asymmetries in the adult and embryo are well known and have been treated at length by Ludwig (1932), who gives a plethora of references. They are considered here only incidentally, and only so far as they are related to more superficial asymmetries. Particular stress is laid on the differences between corresponding structures of the two sides in degree of development, as measured by the number of parts making up these organs. The numerical treatment simplifies the statistical analysis of the data.

BILATERAL VARIATION IN NUMBER OF RAYS IN THE LEFT  
AND RIGHT PECTORAL FINS OF *LEPTOCOTTUS ARMATUS*

Particular emphasis has been placed in the present study on the differences between the two pectoral fins in respect to the number of rays. Among the bilateral asymmetries of fishes this is the one that corresponds most closely to right-handedness and left-handedness in man.

Our attention was directed to this problem during an analysis of meristic variation in *Leptocottus armatus*, a marine cottid fish of western North America. We noted that, when the number of pec-

TABLE VII

ANALYSIS OF ASYMMETRY IN PECTORAL RAY COUNTS OF  
*LEPTOCOTTUS ARMATUS*

*L* indicates that the count is higher on the left side; *R*, that the right fin has the higher number of rays.

| Analyses                                     | <i>N</i> | <i>L</i> | <i>R</i> | 100 ( <i>L</i> + <i>R</i> ) | 100 <i>R</i>        | 100 <i>P</i> |
|----------------------------------------------|----------|----------|----------|-----------------------------|---------------------|--------------|
|                                              |          |          |          | <i>N</i>                    | <i>L</i> + <i>R</i> |              |
| Analysis by localities                       |          |          |          |                             |                     |              |
| 1. Sitkalidak Island, Alaska . . . . .       | 174      | 10       | 19       | 17                          | 66                  | 14           |
| 2. Admiralty Island, Alaska . . . . .        | 104      | 7        | 16       | 22                          | 70                  | 9            |
| 3. Puget Sound, Washington . . . . .         | 245      | 13       | 37       | 20                          | 74                  | 0.1          |
| 4. Grays Harbor, Washington . . . . .        | 103      | 8        | 13       | 16                          | 81                  | 2            |
| 5. Nestucca Bay, Oregon . . . . .            | 136      | 6        | 18       | 18                          | 75                  | 3            |
| 6. Humboldt Bay, California . . . . .        | 221      | 13       | 31       | 20                          | 70                  | 1            |
| 7. San Francisco Bay region . . . . .        | 223      | 17       | 32       | 22                          | 65                  | 3            |
| 8. Elkhorn Slough, California* . . . . .     | 145      | 8        | 25       | 23                          | 76                  | 0.5          |
| 9. Morro Bay, California . . . . .           | 218      | 14       | 30       | 20                          | 68                  | 2            |
| 10. Near Santa Barbara, California . . . . . | 397      | 33       | 49       | 21                          | 60                  | 10           |
| 11. Anaheim Bay, California . . . . .        | 109      | 7        | 25       | 29                          | 78                  | 0.3          |
| 12. Mission Bay, California . . . . .        | 119      | 10       | 19       | 24                          | 66                  | 14           |
| Analysis by subspecies                       |          |          |          |                             |                     |              |
| 1-7. <i>L. a. armatus</i> † . . . . .        | 1,214    | 69       | 167      | 19                          | 71                  | 0.00         |
| 8. Intergrades* . . . . .                    | 145      | 8        | 25       | 23                          | 76                  | 0.5          |
| 9-12. <i>L. a. australis</i> ‡ . . . . .     | 847      | 65       | 124      | 22                          | 66                  | 0.00         |
| Grand total . . . . .                        | 2,206    | 142      | 316      | 21                          | 69                  | 0.00         |

\* Including nineteen specimens from Monterey Bay at Monterey and three from Old Creek near Cayucos, California.

† Including eight specimens from Santa Cruz, California.

‡ Including four specimens from Lower California.

toral rays differs on the two sides, the count for the right fin is usually the higher (Table VII). This relation holds for all twelve localities, from each of which a large sample was studied. In about one specimen in four or five the counts are asymmetrical (the percentage of asymmetry varies from 16 to 29, and usually runs from 20 to 25). Among the asymmetrical specimens from 60 to 81 per cent are right-handed, in the sense that the right pectoral fin (corresponding to the hand) has more rays than the left fin. The differences are of probable to almost certain reliability; the odds of significance are at least 7:1, usually much higher. When the asymmetrical counts are summed up for the two subspecies, the probability that the indicated excess of right-handedness was caused by chance is seen by the  $\chi^2$  test to be less than 1 in 20,000.

As a question of methodology it should be noted that much more decisive results were obtained by applying the  $\chi^2$  test to the fifth part of the counts (those that are asymmetrical) than by following the customary method of using all the counts to analyze the difference between the means for the two sides. When the latter course is followed, the bilateral differences are obscured by the mass of symmetrical counts, and the  $P$  values are much higher, that is, less indicative of significance (Table VIII).

TABLE VIII  
COMPARISON OF AVERAGE NUMBER OF PECTORAL RAYS IN  
*LEPTOCOTTUS ARMATUS*

|                                  | Specimens | Mean $\pm$ SE   |                  | Difference<br>(R - L) | t   | 100 P |
|----------------------------------|-----------|-----------------|------------------|-----------------------|-----|-------|
|                                  |           | Left fin<br>(L) | Right fin<br>(R) |                       |     |       |
| <i>L. a. armatus</i>             |           |                 |                  |                       |     |       |
| Sitkalidak Island, Alaska .....  | 174       | 19.42 $\pm$ .04 | 19.47 $\pm$ .04  | 0.05                  | 0.8 | 42    |
| Admiralty Island, Alaska .....   | 104       | 19.20 $\pm$ .05 | 19.29 $\pm$ .05  | 0.09                  | 1.3 | 19    |
| Puget Sound, Washington .....    | 245       | 18.98 $\pm$ .03 | 19.08 $\pm$ .03  | 0.10                  | 2.5 | 1     |
| Grays Harbor, Washington .....   | 103       | 18.86 $\pm$ .05 | 18.96 $\pm$ .05  | 0.10                  | 1.4 | 16    |
| Nestucca Bay, Oregon .....       | 186       | 18.93 $\pm$ .04 | 19.01 $\pm$ .04  | 0.08                  | 1.3 | 19    |
| Humboldt Bay, California .....   | 221       | 18.91 $\pm$ .03 | 19.00 $\pm$ .03  | 0.09                  | 2.2 | 3     |
| San Pablo Bay, California .....  | 187       | 18.45 $\pm$ .05 | 18.54 $\pm$ .05  | 0.09                  | 1.3 | 19    |
| Intergrades                      |           |                 |                  |                       |     |       |
| Elkhorn Slough, California ....  | 125       | 18.35 $\pm$ .05 | 18.44 $\pm$ .05  | 0.09                  | 1.3 | 19    |
| <i>L. a. australis</i>           |           |                 |                  |                       |     |       |
| Morro Bay, California .....      | 218       | 18.28 $\pm$ .03 | 18.35 $\pm$ .03  | 0.07                  | 1.8 | 7     |
| Near Santa Barbara, California . | 397       | 18.37 $\pm$ .03 | 18.40 $\pm$ .03  | 0.03                  | 0.7 | 48    |
| Anaheim Bay, California .....    | 109       | 18.42 $\pm$ .06 | 18.59 $\pm$ .06  | 0.17                  | 2.0 | 5     |
| Totals and weighted means ..     | 1,864     | 18.72           | 18.80            | 0.08                  | ..  | ..    |

Throughout its long coastal range *Leptocottus armatus* is clearly right-handed in the sense that the right fin usually has the larger number of rays when the number in the two fins is different. The significance of this relationship becomes clearer on further analysis.

The independent variation of the two pectorals in number of rays, leading to a higher number in one fin than the other, is partly counteracted by the tendency for the two fins to vary together in number of rays. The coefficients of correlation for the twelve localities vary from 0.56 to 0.73, with standard errors ranging from 0.03 to 0.06; for *Leptocottus armatus armatus*,  $r = 0.61 \pm 0.05$ ; for *L. a. australis*,  $r = 0.67 \pm 0.04$ ; for the species as a whole,  $r = 0.63 \pm 0.05$ . For all the coefficients the significance is below the 1 per cent ( $P = 0.01$ ) level, indicating a highly reliable correlation.

When the number of pectoral rays is higher in one fin than in the opposite fin, the count in the first fin is usually higher than the mean value for both fins. In other words, in respect to the number of rays the two pectoral fins show a positive correlation between deviation from partner and deviation from mean. The pertinent coefficients of correlation range for the twelve localities from 0.37 to 0.60, with only one value above 0.48. The corresponding standard errors range from 0.03 to 0.06, and  $P$  is consistently below 0.01. For the northern and southern subspecies, respectively,  $r = 0.44 \pm 0.05$  and  $0.43 \pm 0.04$ .

In counting the rays in hundreds of pectoral fins of *Leptocottus* it became evident that the lowermost ray in a given fin was usually short when the ray count was high, and that this ray was ordinarily long when the count was low. Consequently, to test this observation and to analyze the relationship the lowermost ray of each pectoral was measured in numerous specimens from five localities. The measurements were made to the nearest 0.1 mm. and converted into thousandths of the standard length of the fish. For each locality the inverse relationship between number of rays and length of lowest ray was reliably established (Table IX).

It would seem that the small ventralmost ray usually present in pectoral fins having a high number of rays might be given a lower numerical value (some fractional value) than is assigned to the larger corresponding ray usually occurring in fins with fewer rays. On this basis there would be less than 1.0 ray difference between

TABLE IX

RELATION BETWEEN NUMBER OF PECTORAL RAYS AND AVERAGE LENGTH OF LOWERMOST RAY IN FIVE SERIES OF *LEPTOCOTTUS ARMATUS*

The average lengths of the rays are expressed in thousandths of the standard length. The underlying values in parentheses represent the standard errors of these means and the number of lowermost rays measured for each fin with the given total number of rays.

|                                                              | Number of rays in pectoral fin |    |                        |                        |                        |                        |                      |
|--------------------------------------------------------------|--------------------------------|----|------------------------|------------------------|------------------------|------------------------|----------------------|
|                                                              | 15                             | 16 | 17                     | 18                     | 19                     | 20                     | 21                   |
| Near Santa Barbara, California (168 specimens; $M = 18.38$ ) | 69.0? ( $\pm 7$ ; 1)           | .. | 72.0 ( $\pm 1.1$ ; 22) | 63.9 ( $\pm .6$ ; 183) | 54.2 ( $\pm .7$ ; 128) | 46.5? ( $\pm 7$ ; 2)   | ..                   |
| Mission Bay, California (137 specimens; $M = 18.79$ )        | ..                             | .. | 72.7? ( $\pm 7$ ; 3)   | 64.1 ( $\pm 1.0$ ; 66) | 53.0 ( $\pm .6$ ; 190) | 46.9 ( $\pm 2.0$ ; 15) | ..                   |
| Grays Harbor, Washington (101 specimens; $M = 18.91$ )       | ..                             | .. | 69.5? ( $\pm 7$ ; 2)   | 67.6 ( $\pm 1.2$ ; 33) | 58.0 ( $\pm .7$ ; 148) | 45.0 ( $\pm 1.0$ ; 19) | ..                   |
| Nestucca Bay, Oregon (136 specimens; $M = 18.97$ )           | ..                             | .. | ..                     | 64.8 ( $\pm 1.1$ ; 39) | 56.0 ( $\pm .8$ ; 202) | 48.0 ( $\pm .9$ ; 31)  | ..                   |
| Sitkalidak Island, Alaska (91 specimens; $M = 19.40$ )       | ..                             | .. | ..                     | 67.6? ( $\pm 7$ ; 5)   | 67.7 ( $\pm .8$ ; 103) | 55.4 ( $\pm .9$ ; 77)  | 47.7? ( $\pm 7$ ; 3) |

the two fins when, for example, the counts are 18 left and 19 right, for the eighteenth ray of the left fin is more of a ray than is the nineteenth element of the right fin. Convention and convenience demand that the rays be enumerated as whole numbers, but it is important to keep in mind that the classes of ray counts could be indefinitely divided, according to the degree of development of the last ray. Not only for the pectoral fins but also for many other meristic series we are finding that there are many gradations between the successive counts; that is, that there is no real distinction between continuous and discontinuous (or discrete) variations. We expect to deal with this problem in a separate paper. For the present it may suffice to state that the lowermost pectoral ray in *Leptocottus* varies from the merest rudiment to a large ray, providing all transitional conditions between successive counts (of 18 and 19, for example).

The degree of development of pectoral fins with any given ray count is best measured by the size of the lowermost ray. This ray



varies much more in length than any other one and is the only one that grades into a rudiment. It is presumably the last to be formed in ontogeny. It may be assumed that, when an embryonic fin is larger than usual, it will develop an extra ray at the lower edge. If the fin in the embryo is smaller than usual, the lowermost ray will presumably be the one that fails to form. A slight increase in fin size at the critical time of ray formation would leave room for only a minute ray; a larger increase would permit a larger ray to be developed at the lower fin margin. This reasoning is in line with the idea that meristic elements such as vertebrae, scales, and fin rays are laid down at a relatively constant distance apart, in absolute terms, and that the number of elements developed depends on the space available, up to the time when development stops. It is immaterial whether the elements are formed simultaneously in a given space or whether the formation of parts continues as the space for development increases. In either case the potentiality for segment formation eventually ceases, and thus fixes a limit to the space over which the segments may form, either on one occasion or over a period of time. The number of parts laid down will then be proportional to the available space. Such an explanation seems to hold for the number of scales that are formed over the body (Hubbs, 1941a; Neave, 1943:81-82) and is applicable to the determination of the number of elements in various meristic series (Hubbs, 1926b).

Although the discussion may be oversimplified, one may continue with the same line of reasoning, using a diagram (Fig. 1) to help visualize the relations which the size of the pectoral fin at the time when the formation of new rays at the ventral edge ceases bears to the number of pectoral rays and to the size of the lowest ray in each fin. Let 5 be the usual condition, representing a pectoral fin with 18 rays of which the eighteenth is of moderate size, but longer on the right than on the left side. Fins 4, 3, 2, and 1 on the right side represent successively smaller fins, in which room is left at the lower end first for a short ray 18, then for a very long ray 17 (since there is now no room for ray 18 to form), next for a rather long ray 17, and finally for a ray 17 of moderate length. Further steps in the same direction would yield a fin with only 16 rays. On the left side similar changes take place, but ray 18 drops out sooner. Fins 6, 7, 8, and 9 on the right side are progressively larger, and

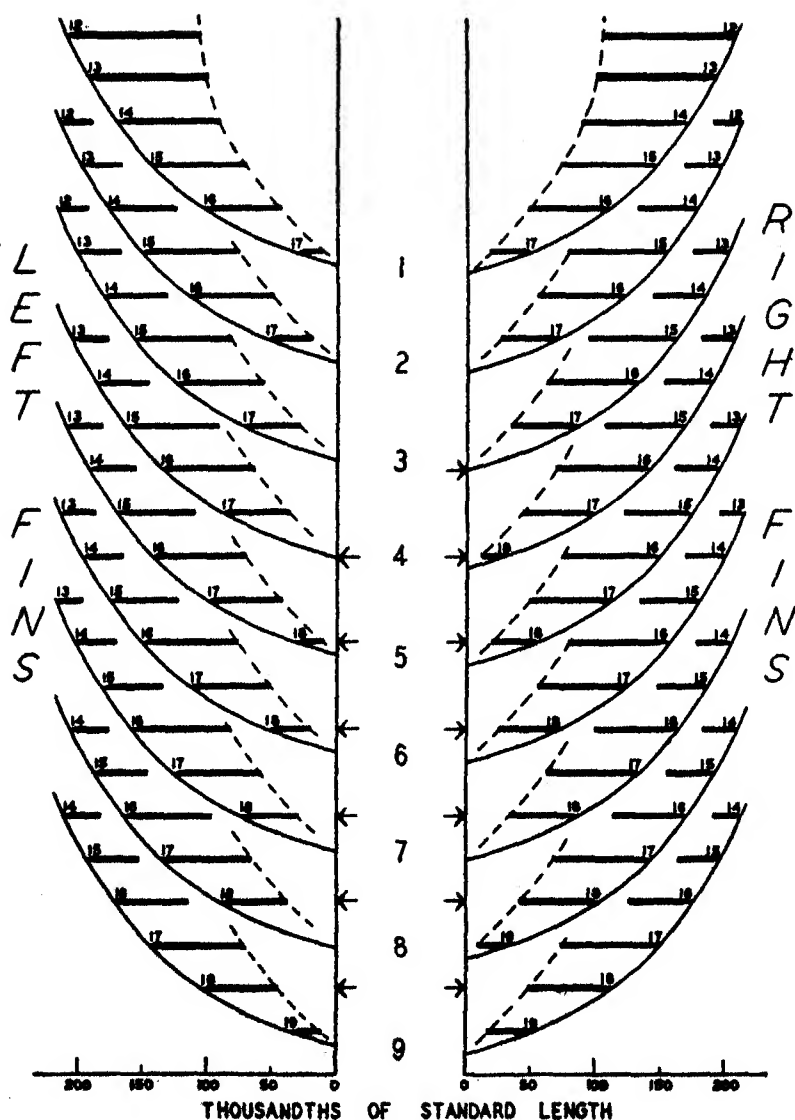


FIG. 1. Diagrams of lower portion of left and right pectoral fins of *Leptocottus armatus*, to illustrate the theory that the number of rays and the length of the lowermost ray are correlated with the size of the fin. The arrows point to the position of ray 18.

are characterized by an increasing length of the eighteenth ray; eventually there is added a nineteenth ray, at first small, then of moderate size. Further increases would allow for a still longer nineteenth ray and occasionally for yet another ray, giving a count of 20. On the left side similar changes again occur, but ray 19 is not added so soon. By the rule of normal variation fins of type 5 are most abundant, since this is taken as the mean condition, and the number of each type decreases in both directions. The diagram visualizes the lesser development of the left side, in terms both of average number of rays and of the size of the lowermost ray when the number is alike on the two sides. In the far north, where the pectoral rays are more numerous, the base of variation is shifted so that the nineteenth ray now replaces the eighteenth as the lowermost ray that is of moderate length (Table IX).

It seems clear that the number of rays in the pectoral fin is positively associated with sidedness, for the right fins have a higher average number of rays than the left fins. The interpretation has just been reached that the length of the lowermost pectoral ray is correlated positively with the total number of rays in the fin. When these relations were both determined, it was concluded that the size of the lowermost ray should differ in average length on the two sides, even when the ray counts are symmetrical.

It was observed that the fin which has the larger number of rays has the lowermost ray smaller than the corresponding ray of the opposite fin. Again following the reasoning illustrated by Figure 1 we conclude that the positive correlation between the two fins should render this relation almost invariable. When one fin (more commonly the right) is differentially enlarged sufficiently to introduce a new, short ray at the lower border, the opposite fin, with one ray fewer, should be somewhat enlarged, too, so that its last ray will be large. When one fin is differentially decreased just enough to eliminate a ray, the last ray becomes a large one; the other fin should be nearly as much reduced and should retain the extra ray, of a small size. The correlation was indeed found to be all but invariable in *Leptocottus* and almost as consistent in *Cottus bairdii* (p. 274). It was checked in 421 of the 458 specimens of *Leptocottus* that have asymmetrical pectoral ray counts. Of the 421 all but one had the lowermost ray the smaller in the fin having the higher count. In the one exception the last ray of the fin with

TABLE X

RELATIVE LENGTHS OF THE LOWERMOST RAY IN THE TWO PECTORAL  
FINS OF *LEPTOCOTTUS ARMATUS*

The consistent data for the five localities mentioned in Table IX have been combined. Specimens with no measured difference between the lengths of the lowermost ray of the two sides are equally apportioned among those having the ray longer on the left side and those having the ray longer on the right.

|                            | Difference between lengths of lowermost pectoral rays of the two sides, in thousandths of the standard length |                  |     |                 |       |        |       |       |       |       |
|----------------------------|---------------------------------------------------------------------------------------------------------------|------------------|-----|-----------------|-------|--------|-------|-------|-------|-------|
|                            | 0                                                                                                             | 1-4              | 5-8 | 9-12            | 13-16 | 17-20  | 21-24 | 25-28 | 29-32 | 33-36 |
| Ray counts equal           |                                                                                                               |                  |     |                 |       |        |       |       |       |       |
| Ray longer in left fin ... | 33.5                                                                                                          | 86               | 43  | 15              | 8     | 1      | ..    | ..    | 1     | ..    |
| Ray longer in right fin .. | 33.5                                                                                                          | 119              | 90  | 51              | 16    | 4      | 2     | ..    | ..    | 1     |
| Left fin with more rays    |                                                                                                               |                  |     |                 |       |        |       |       |       |       |
| Ray longer in right fin .. | ..                                                                                                            | 1                | ..  | 3               | 8     | 10     | 11    | 5     | 4     | 1     |
| Right fin with more rays   |                                                                                                               |                  |     |                 |       |        |       |       |       |       |
| Ray longer in left fin ... | ..                                                                                                            | 2                | 4   | 11              | 16    | 23     | 14    | 8     | 7     | ..    |
| Ray longer in right fin .. | ..                                                                                                            | ..               | 1   | ..              | ..    | ..     | ..    | ..    | ..    | ..    |
|                            | Statistical calculations                                                                                      |                  |     |                 |       |        |       |       |       |       |
|                            | Mean *                                                                                                        | No. of specimens |     |                 |       | 100 P  |       |       |       |       |
|                            |                                                                                                               | $\Delta = 0-4$   |     | $\Delta = 5-36$ |       |        |       |       |       |       |
| Ray counts equal           |                                                                                                               |                  |     |                 |       |        |       |       |       |       |
| Ray longer in left fin ... | 4.18                                                                                                          | 119.5            |     | 68              |       | 0.07 † |       |       |       |       |
| Ray longer in right fin .. | 5.58                                                                                                          | 152.5            |     | 164             |       |        |       |       |       |       |
| Left fin with more rays    |                                                                                                               |                  |     |                 |       |        |       |       |       |       |
| Ray longer in right fin .. | 20.23                                                                                                         | 1                |     | 42              |       | 11 §   |       |       |       |       |
| Right fin with more rays   | 18.01 ‡                                                                                                       | 2                |     | 84              |       |        |       |       |       |       |
| Ray longer in left fin ... | 18.31                                                                                                         | 2                |     | 83              |       |        |       |       |       |       |
| Ray longer in right fin .. | 7.07                                                                                                          | ..               |     | 1               |       |        |       |       |       |       |

\* Means were derived from uncombined data.

† This 100 P value, derived from the  $\chi^2$  test, estimates the reliability of the distribution of the data according to whether the difference is none to slight (0-4) or moderate to large (5-36).

‡ In computing this mean the value of 7 (for the specimen with the longer lowermost ray in a right pectoral with the higher ray count) is included as a minus figure.

§ This 100 P value estimates the reliability of the difference between the means, and is computed from the uncombined frequencies. In determining  $t$  and hence  $P$  the correction for diverse size of samples was used.

more rays (the right fin) was only 0.007 of the standard length longer than the corresponding ray of the left fin. The last pectoral ray averaged 0.019 of the standard length shorter in the fin with the higher number of rays, and was found to be more than 0.008 shorter in 118 out of 126 specimens (Table X). The difference in the length of the ray appears to be somewhat greater when the left fin has more rays than the right, presumably because the lowermost ray of the left fin has two reasons for being small: because it is in the fin with the higher ray count and because it is on the left side. The lowest ray of the right fin correspondingly has a double reason for being especially large: it is in the fin with the fewer rays and it is on the favored right side. The difference, however, is not of assured statistical reliability.

The most significant result obtained from measuring the length of the lowermost pectoral ray — the most sensitive criterion of the degree of development of the fin at the time the rays are formed — is the indication that on the average the right fin is the better developed even when the ray count is the same on the two fins. The evidence for right-handedness is, therefore, not limited to the fins with different ray counts, and the proportion of rights to lefts is greater than is indicated by the ray counts alone. The better development of the right fin is measured by the greater difference between the length of the last ray of this fin and that of the left fin, when the number of rays in the two fins is the same and when the lowermost ray of the right fin is the longer. The contrast is often striking. The moderate to large differences, of 5 to 36 thousandths of the standard length — those large enough to be observable and to be well beyond the error of measurement — are much more frequent when the right ray is the longer. When the left ray is the longer the difference is more often none to slight (0 to 4 thousandths of the standard length). The  $\chi^2$  test indicates that a very reliable distinction exists in the distribution of the data according to whether the difference in ray length for the two fins is none to slight, 0 to 4, or moderate to large, 5 to 36:  $\chi^2 = 11.41$ ;  $P = 0.0007$ .

#### BILATERAL VARIATION IN NUMBER OF RAYS IN THE TWO PECTORAL FINS OF OTHER FISHES

After having found that the number of pectoral rays is higher on the right oftener than on the left side of *Leptocottus armatus*,

we turned our attention to published and original data on other fishes (Table XI), to learn whether what might be called right-handedness is of universal occurrence in fishes. The most pertinent published data were presented by the distinguished German student of variation Georg Duncker.

In a European percid, *Acerina cernua*, Duncker (1897: 819, 830; 1900: 359; 1904: 560-562, 647, 651) found the asymmetrical counts to be divided nearly equally between lefts and rights. The ratios were 92: 93 for 1,000 females and 65: 49 for 650 males. He seemed to have some reliance on the indicated tendency toward sinistrality in the males, but Ludwig (1932: 4-7), in reviewing the same data, regarded the counts as symmetrical. The  $\chi^2$  test indicates the difference to be wholly untrustworthy.

In one moderately adequate sample of another cottid, the European fresh-water *Cottus gobio*, results very much like those here given for *Leptocottus* were secured by Duncker (1897: 830; 1904: 567-568, 647, 652), who stated that dextrality was also evident in a smaller series (150 specimens) of the marine cottid *Myoxocephalus scorpius*. Duncker regarded the preponderance of higher ray counts in the right pectorals as significant, but Ludwig (1932: 6), who arbitrarily fixed a limit of reliability at about 0.05 in Duncker's coefficient of asymmetry (see p. 232), regarded the fins of *Cottus gobio* as probably symmetrical. On the  $\chi^2$  test the difference (20 L: 42 R) appears trustworthy.

Duncker (1908: 55, 103) discovered that at three localities the European pipefish *Syngnathus typhle* also has a higher count of rays in the right pectoral oftener than in the left fin.

Duncker's results, except for the neutral case of *Acerina*, thus stand in line with our findings on *Leptocottus*. To test this indication that fishes are predominantly right-handed in respect to the number of pectoral rays, new counts were taken on large series of two other species of the Cottidae, and pectoral ray counts of several species of cyprinodont and cyprinid fishes, previously made during other studies in our laboratory, were analyzed to see whether they, too, showed any significant bilateral asymmetry (Table XI).

The results for *Cottus bairdii bairdii* stand nicely in line with the data we secured on *Leptocottus armatus* and with those given by Duncker for *Cottus gobio*. The 1,372 specimens counted constituted a definite unit, for they were all taken in one poisoning of a

TABLE XI

BILATERAL VARIATION IN NUMBER OF RAYS IN THE  
TWO PECTORAL FINS OF VARIOUS FISHES

This table supplements Table VII. For source of data and other details refer to the accompanying text.

|                                        | N     | L   | R   | $\frac{100(L+R)}{N}$ | $\frac{100R}{L+R}$ | 100 P |
|----------------------------------------|-------|-----|-----|----------------------|--------------------|-------|
| Cottidae                               |       |     |     |                      |                    |       |
| <i>Cottus bairdii bairdii</i> .....    | 1,372 | 73  | 223 | 22                   | 75                 | 0.00* |
| <i>Cottus gobio</i> .....              | 354   | 20  | 42  | 18                   | 68                 | 0.5   |
| <i>Clinocottus analis australis</i> .. | 976   | 58  | 45  | 11                   | 44                 | 20    |
| Syngnathidae                           |       |     |     |                      |                    |       |
| <i>Syngnathus typhle</i> † .....       | 1,290 | 103 | 155 | 20                   | 60                 | 0.1   |
| Percidae                               |       |     |     |                      |                    |       |
| <i>Acerina cernua</i> .....            | 1,650 | 157 | 142 | 18                   | 47                 | 38    |
| Cyprinodontidae                        |       |     |     |                      |                    |       |
| <i>Cyprinodon nevadensis</i> .....     | 1,725 | 261 | 178 | 25                   | 41                 | 0.00  |
| <i>Oryzias latipes</i> .....           | 368   | 74  | 44  | 32                   | 37                 | 0.6   |
| Poeciliidae                            |       |     |     |                      |                    |       |
| <i>Mollienisia sphenops</i> .....      | 743   | 74  | 63  | 18                   | 46                 | 35    |
| Cyprinidae                             |       |     |     |                      |                    |       |
| <i>Siphateles</i> , several forms ...  | 365   | 55  | 50  | 29                   | 48                 | 62    |

\* A 100 P value of 0.00 indicates odds less than 1 in 20,000 that the result obtained is due to chance.

† The data are consistent for three localities.

spring pool on the grounds of the Wolf Lake Hatchery, Michigan. There were found 296 fish with the pectoral ray count different on the two sides, and of these the right count was the higher in 223; the left count, in only 73. The odds are much more than 1,000,000 to 1 against obtaining this difference by chance. The detailed statistical relations between the ray counts of the left and right fins of *Cottus bairdii* also agree beautifully with those for *Leptocottus armatus*. Thus the coefficient of correlation between the two counts is  $0.64 \pm 0.02$ . There is also a strong positive correlation between the deviation of each count from the mean and the deviation of the same enumeration from the count of the partner fin. The lowermost ray of the fin with the higher ray count is shorter than the corresponding element of the opposite fin in 288, or 97 per cent,

of the 296 specimens with asymmetrical counts (it was the longer in the eight other specimens). The mean for the left fin is 14.586, with standard error 0.0170; for the right fin,  $14.696 \pm 0.0166$ . The  $t$  value is 4.62 and the probability that the difference is due to chance is only 4 in 1,000,000. Thus, with sufficiently large samples (decreasing the standard errors), reliable indications of left-right asymmetry can be obtained by statistically comparing the means for the counts for the two sides.

The indication that the cottoid fishes are uniformly right-handed received a setback when the pectoral ray counts were made on 976 specimens of *Clinocottus analis australis*, collected on various dates in the tide pools of the adjacent headlands of Point Fermin and Whites Point, San Pedro, California. The ratio of lefts to rights in the 11 per cent of the specimens with asymmetrical counts proved to be 58:45. The chances are five to one that the left fin has on the average more rays than the right when the number differs on the two sides. The odds against *Clinocottus* being as strongly right-handed as *Leptocottus australis* or *Cottus bairdii* are almost infinitely large. How unsafe it is to generalize!

Slight to certain indications of sinistrality in the pectoral fins, as indicated by the number of rays, come also from counts of three cyprinodont fishes, and a bare suggestion of left-handedness is furnished by 105 counts for several forms of *Siphateles*, a genus of Cyprinidae from the American deserts (Table XI). The counts for *Cyprinodon nevadensis*, which were kindly made available by Robert R. Miller, pertain to various isolated subspecies living in the springs of the Death Valley region, California and Nevada. Virtually all the populations of the species are included in the data, and no indication was obtained that the races differ greatly in their tendency to be left-handed. The counts on *Oryzias latipes*, the *medaka* of the Japanese rice fields, were taken on series from many parts of Kyûshyû and Honshyû. Those for *Mollienisia sphenops* were made by Research Assistant W. Robert Martin on various subspecies from Guatemala and Mexico.

#### BILATERAL VARIATION IN NUMBER OF RAYS IN THE TWO PELVIC FINS

Moderately trustworthy figures indicate that the pelvic fin of *Leptocottus armatus* agrees with the pectoral fin in being better



developed on the right than on the left side (Table XII). The asymmetrical counts are so few, however, that separate analysis by localities is unwarranted. Out of a total of 3,208 specimens from all places only 58 had the count different on the two sides — 24 on

TABLE XII

BILATERAL VARIATION IN NUMBER OF RAYS IN THE  
TWO PELVIC FINS OF FISHES

For source of data and other details see text.

|                                                 | <i>N</i> | <i>L</i> | <i>R</i> | $\frac{100 (L + R)}{N}$ | $\frac{100 R}{L + R}$ | 100 <i>P</i> |
|-------------------------------------------------|----------|----------|----------|-------------------------|-----------------------|--------------|
| <i>Leptocottus armatus</i>                      |          |          |          |                         |                       |              |
| All counts (a) .....                            | 3,208    | 24       | 34       | 2                       | 59                    | 19           |
| Inner ray rudimentary in opposite fin (b) ..... | 3,208    | 20       | 38       | 2                       | 66                    | 2            |
| Sum, a + b .....                                | 3,208    | 44       | 72       | 4                       | 62                    | 0.9          |
| <i>Cyprinodon nevadensis</i> .....              | 1,821    | 313      | 280      | 33                      | 47                    | 18           |
| <i>Siphateles obesus pectinifer</i> .....       | 409      | 43       | 15       | 14                      | 26                    | 0.02         |
| <i>Siphateles</i> , several forms .....         | 1,884    | 182      | 112      | 16                      | 38                    | 0.00         |
| <i>Rhinichthys osculus</i> .....                | 727      | 47       | 42       | 12                      | 47                    | 78           |

the left and 34 on the right. The greater weakness of the left side was better shown by the occasional rudimentation of the last ray. If we count this condition as *R* and the opposite situation as *L*, the ratio of variants is 20 *L*:38 *R*. Combining the two sets, we find 44 sinistral to 72 dextral fish, in regard to the development of the pelvic fin. On this basis the distinction is rather trustworthy (see table). Usually there was no question whether or not the last ray was to be counted as rudimentary, for such a ray as a rule was very slender and was much less than half the length of the other rays. Often this ray could be detected only with good light and high magnification. A conscious effort was made to avoid the personal error of treating a ray as rudimentary in the left fin when a ray equally reduced was not so listed for the right fin. The recorded difference is thought attributable neither to chance nor to personal error. Somewhat figuratively we might speak of *Leptocottus armatus* as moderately right-footed.

Other fishes, however, are found to have the higher count oftener in the left pelvic than in the right fin (Table XII). This is almost

certainly true of the cyprinid fish *Siphateles*, as is indicated not only by the sum of counts of many series from different waters in the Great Basin, but also by the asymmetrical counts (43 lefts to 15 rights) among 409 additional enumerations for a single collection of *Siphateles obesus pectinifer* seined at one time along a beach of Walker Lake, Nevada. The results for the *Cyprinodon nevadensis* material (the same as that used for the pectoral counts) are by no means conclusive, but suggest that this species also may have the left pelvic fins slightly better developed than their right mates. No significant difference is indicated for *Rhinichthys osculus* (several subspecies).

The suckers (Catostomidae) show an unusually high percentage of bilateral asymmetry in the number of pelvic rays, and would therefore furnish excellent material to determine which fin, if either, more commonly has the higher count. Of 1,772 specimens counted 338, or 19 per cent, had the pelvic fins asymmetrical in the number of rays. Most of the counts, however, were made in other researches, and too few have been tabulated according to the side having the higher ray count to provide more than a hint that these fishes may also be slightly sinistral in respect to the pelvic fins.

In *Cyprinodon nevadensis*, which often lacks the pelvic fin on one or both sides (Miller, 1943:9-11), there is an indication of sinistrality, in the sense that the right fin seems to atrophy oftener than the left. Of 1,822 fish counted by Miller 112 (6 per cent) have one pelvic missing, and of these the fin is lacking on the left side in 47 specimens and on the right side in 65 ( $\chi^2 = 2.91$ ;  $P = 0.09$ ). In a race of wild carp (*Cyprinus carpio*) often lacking one or both pelvic fins Thompson and Adams (1936) found that the fin might be missing on either the left or the right side or on both sides, but they did not give the ratios.

#### ASSOCIATION BETWEEN ASYMMETRICAL DEVELOPMENT OF PECTORAL AND PELVIC FINS

Very little evidence is available to test the query, Is there an association between the better development, as measured by ray counts, of the pectoral and the pelvic fins? That is, to speak semi-figuratively, are right-handedness and right-footedness and left-handedness and left-footedness associated in the individual fish? The data for *Leptocottus armatus* and *Cyprinodon nevadensis* (Table

XIII) show no significant association, as measured by the  $\chi^2$  test. Fish with more right than left pectoral rays often have more left than right pelvic rays. As yet there is no reason to assume that any definite association or correlation exists between the differential bilateral development of the pectoral and the pelvic fins.

TABLE XIII

ASSOCIATION BETWEEN RIGHT-LEFT VARIATIONS IN NUMBER OF  
PECTORAL AND PELVIC RAYS

The counts were made by Carl L. Hubbs on 1,670 specimens of *Leptocottus armatus*, representing localities from Lower California to southwestern Alaska, and by Robert R. Miller on 1,724 specimens of *Cyprinodon nevadensis*, representing virtually all populations of this desert fish of the Death Valley region. For the counts of the *Cyprinodon* that are asymmetrical in both fins,  $\chi^2 = 0.75$ ; the corresponding *P* value is 0.39.

|                                      | Count higher in |                  |                |
|--------------------------------------|-----------------|------------------|----------------|
|                                      | Left pectoral   | Neither pectoral | Right pectoral |
| <i>Leptocottus armatus</i>           |                 |                  |                |
| Count higher in left pelvic .....    | 3               | 19               | 4              |
| Count higher in neither pelvic ..... | 98              | 1,295            | 215            |
| Count higher in right pelvic .....   | 1               | 30               | 5              |
| <i>Cyprinodon nevadensis</i>         |                 |                  |                |
| Count higher in left pelvic .....    | 45              | 210              | 33             |
| Count higher in neither pelvic ..... | 177             | 875              | 124            |
| Count higher in right pelvic .....   | 39              | 200              | 21             |

BILATERAL ASYMMETRY AND VARIATION IN BRANCHIOSTEGAL  
CHARACTERS

Some of the most significant yet least noticed of the bilateral asymmetries of fishes relate to the branchiostegal membranes which enclose the branchial chamber ventrally on each side. In species having the two membranes separate that of one side overlaps the other. The overlapping member is the more ventral in position when the membranes are folded together. In some fishes the bony branchiostegal rays which support the soft tissues differ in number on the two sides.

*Overlap of branchiostegal membranes.* — It has already been noted (p. 244) that the few flounders with separate gill membranes follow

the general rule for fishes that the left membrane overlaps the right. This basic asymmetry has generally been overlooked, we believe, except in one paper (Hubbs, 1920). Observations made in connection with other researches, particularly a comparative study by Hubbs and Lagler (MS) on the gill structures of the clupeoid fishes, led us to conclude that the left branchiostegal membrane invariably folds over the right one in all fishes in which the membranes have not become united with each other or with the isthmus. This conclusion is now confirmed by a determination of the overlap relations of these tissues in ten specimens of the ladyfish, *Albula vulpes*, from various localities; in 476 young herring, *Clupea harengus*, from one series taken near Woods Hole; and in 183 fingerling king salmon, *Oncorhynchus tshawytscha*, from streams in Oregon, Washington, and Idaho (Table XIV).

As is true of almost all generalizations in biology, we now find,

TABLE XIV

BILATERAL ASYMMETRY AND VARIATION IN BRANCHIOSTEGAL  
CHARACTERS OF ESSENTIALLY SYMMETRICAL FISHES

For source of data and other details see text.

|                                       | N   | L   | R  | $\frac{100(L+R)}{N}$ | $\frac{100R}{L+R}$ | 100 P |
|---------------------------------------|-----|-----|----|----------------------|--------------------|-------|
| Overlap of branchiostegal membranes   |     |     |    |                      |                    |       |
| <i>Albula vulpes</i> .....            | 10  | 10  | 0  | 100                  | 0                  | 0.4   |
| <i>Clupea harengus</i> .....          | 476 | 476 | 0  | 100                  | 0                  | 0.00  |
| <i>Oncorhynchus tshawytscha</i> ..... | 183 | 183 | 0  | 100                  | 0                  | 0.00  |
| <i>Esox vermiculatus</i> .....        | 442 | 410 | 32 | 100                  | 7                  | 0.00  |
| Number of branchiostegal rays         |     |     |    |                      |                    |       |
| Left membrane overlapping right       |     |     |    |                      |                    |       |
| <i>Albula vulpes</i> .....            | 10  | 9   | 0  | 90                   | 0                  | 0.8   |
| <i>Oncorhynchus tshawytscha</i> ..... | 46  | 37  | 0  | 80                   | 0                  | 0.00  |
| <i>Esox vermiculatus</i>              |     |     |    |                      |                    |       |
| Posterior rays .....                  | 410 | 28  | 58 | 21                   | 67                 | 0.1   |
| Anterior rays .....                   | 410 | 110 | 51 | 40                   | 32                 | 0.00  |
| Total rays .....                      | 410 | 88  | 52 | 34                   | 37                 | 0.2   |
| Right membrane overlapping left       |     |     |    |                      |                    |       |
| <i>Esox vermiculatus</i>              |     |     |    |                      |                    |       |
| Posterior rays .....                  | 32  | 1   | 1  | 6                    | 50?                | ..    |
| Anterior rays .....                   | 32  | 8   | 9  | 37                   | 75                 | 15    |
| Total rays .....                      | 32  | 2   | 8  | 31                   | 80                 | 11    |

however, that in at least one species some exceptions to this rule occur. Among 442 specimens of *Esox vermiculatus* from southern Michigan, examined to determine the bilateral variation in the number of branchiostegal rays, 32 (7 per cent) have the right membrane external. It was a real surprise to note this variation in a character which has remained invariable, in regard to the typical condition, throughout the Holostei and the Teleostei. These data on the folding of the branchiostegal membranes emphasize both the fundamental nature of the left-right relationships in general and their susceptibility to reversal.

Because of the sharp compression of the head the membranes in the herring overlap throughout most of their length. Posteriorly the first three branchiostegals on the right side form a prominent shelf, the recess of which receives the adjacent edge of the left membrane. In this region, therefore, the left membrane overlaps the right one, but is in turn overlapped by a process from the right side.

*Number of branchiostegal rays.* — The rule that the left branchiostegal membrane overlaps the right led us to wonder whether this asymmetry might not be correlated with a bilateral difference in the number of branchiostegal rays. We had noticed for years that the number of these bony stays is often different on the two sides in certain fishes, particularly the Salmonidae (salmons and trouts) and the Esocidae (pikes), but we had made no tabulations to determine whether the counts average the higher on the left or on the right side.

Jordan and Evermann (1896:479) described the branchiostegals of the king salmon, *Oncorhynchus tshawytscha*, as "B. 15 or 16 to 18 or 19, the number on the two sides always unlike," but we know of no correlation of counts with the sides. Examining forty-six fingerlings of this species from Oregon and Washington, we find that the counts are alike on the two sides in 20 per cent of the fish, and that in the other 80 per cent the count is one or two higher on the left side than it is on the right (Table XIV). When the counts are symmetrical the last (anteriormost) ray is often reduced in size or even rudimentary on the right side. *Oncorhynchus tshawytscha* may therefore be classed as strongly sinistral in respect to the number of branchiostegal rays. In this species the left branchiostegal membrane consistently overlaps the right, but only for a short distance

anteriorly, since the two membranes diverge widely backward. In the region of overlap the anteriormost rays are the more deeply covered by tissue on the left side.

An even closer correlation between the character of the two branchiostegal membranes and the number of rays in these membranes seems to hold in the ladyfish, *Albula vulpes* (Table XIV). In this primitive clupeoid the left membrane not only overlaps the right membrane but is also much more expansive. In association with the greater available space the left rays outnumber the right by one or two in nine out of the ten specimens examined; in only one is the number equal on the two sides.

In *Esox vermiculatus* the membranes are subequal in size and the difference in number of rays on the two sides requires long statistical analysis for reliable demonstration (Table XIV). When, as is usual, the left membrane overlaps the right, the left branchiostegals on the average outnumber the right. This is not true, however, of the posterior rays, which are attached to the outer surface of the hyoid arch, behind the posterior insertion of the geniohyoid muscle. These outer, posterior, rays on the average are more numerous on the right side. The anterior rays, which are attached to the inner surface of the arch because they are overlain by the large *m. geniohyoideus*, have the average count definitely higher on the left side. In respect to the number of rays the posterior group of branchiostegals is dextral; the anterior group is strongly enough sinistral to render the total number slightly but significantly higher on the left side. This seeming contradiction finds a plausible explanation in the better average development of the geniohyoid muscle on the left side when the left membrane overlaps the right. The extent of this muscle is no doubt correlated with the number of anterior rays.

When the right branchiostegal membrane overlaps the left, as it does in 32 of the 442 specimens of *Esox vermiculatus* studied, the numerical relations of the branchiostegal rays seem also to be reversed (Table XIV). Now the anterior rays and the total rays on the right side appear to outnumber those on the left. Because of the small number of specimens the difference between the sides, though probable, is by no means certain. For the anterior rays and the total rays, however, the relative numbers of rights and lefts can be regarded as reliably different in the two lots (those with

the left membrane overlapping and those with the right membrane the more external); the probability of obtaining ratios of 110:51 and of 3:9 from two parts of a homogeneous series is about 2 in 1,000; the probability of getting counts of 88:52 and of 2:8 from two samples of a homogeneous whole is about 8 in 1,000. The direction of overlap of the membranes and the different muscular development along the hyoid arches of the two sides seem to be more significant than leftness or rightness as such, as a correlative of ray number.

Such bilateral differences in the number of branchiostegal rays will probably be found to occur in relatively few fishes. The acanthopterygian fishes and their relatives have a low number of branchiostegals (4 posterior + 0 to 4 anterior), and the number is often constant for species and even families (Hubbs, 1920). In many soft-rayed fishes also the number is constant within families (for example, three throughout the Cyprinidae and Catostomidae). Differences between the sides are to be looked for among those malacopterygian fishes which, like *Albula*, *Esox*, and the Salmonidae, have a high and variable number of branchiostegals.

It will be interesting to determine whether average differences exist between the numbers of gill rakers on the arches of the left and right sides. No pertinent counts seem to be available.

#### BILATERAL ASYMMETRY AND VARIATION IN OTHER CHARACTERS

The paired fins and the branchiostegal membranes and rays are by no means the only bilateral structures of fishes that may be differentially developed on the two sides. Several additional characters have been tested, and an indefinite number remain to be studied. The few analyses that have been made support the impression gained from systematic studies that the various bilateral organs are generally about equally developed on the two sides. The left and right elements of a few structures, however, differ markedly in average number or in other indices of relative development.

*Scales and plates.* — The only extensive comparison of the right and left scale counts on individual fishes which we have found is that by Voris (1899: 236–237), whose data for the minnow *Hyborhynchus notatus* were reanalyzed by Duncker (1904: 578, 647, 653) and Ludwig (1932: 6). The difference between counts higher on the right

TABLE XV

BILATERAL VARIATION IN SCALE, GILL, AND TOOTH CHARACTERS AND IN MEASUREMENTS OF FISHES

For source of data and other details see text.

|                                           | N   | L   | R   | $\frac{100(L+R)}{N}$ | $\frac{100R}{L+R}$ | 100 P |
|-------------------------------------------|-----|-----|-----|----------------------|--------------------|-------|
| Lateral-line scales                       |     |     |     |                      |                    |       |
| <i>Hyborhynchus notatus</i> .....         | 500 | 144 | 169 | 62                   | 54                 | 16    |
| Plates along fin bases, <i>Zeus faber</i> |     |     |     |                      |                    |       |
| Along dorsal base .....                   | 250 | 68  | 76  | 58                   | 53                 | 50    |
| Along anal base .....                     | 250 | 65  | 61  | 50                   | 48                 | 72    |
| Dorsal plus anal plates .....             | 250 | 79  | 79  | 63                   | 50                 | 100   |
| Gill slits in hagfish                     |     |     |     |                      |                    |       |
| <i>Bdellostoma stouti</i> .....           | 550 | 62  | 33  | 17                   | 35                 | 0.3   |
| Teeth on rostrum, sawfishes               |     |     |     |                      |                    |       |
| <i>Pristis</i> , three or more species... | 84  | 20  | 28  | 57                   | 58                 | 31    |
| Measurements, <i>Acerina cernua</i>       |     |     |     |                      |                    |       |
| Head length .....                         | 692 | 76  | 60  | 20                   | 44                 | 16    |
| Mandible length .....                     | 692 | 86  | 103 | 27                   | 54                 | 21    |

side and those greater on the left is small and hardly of trustworthy significance (Table XV). For 600 specimens of *Percina caprodes* from Turkey Lake, Indiana, Moenkhaus (1895:282-283) gave an average of 89.46 for the left lateral-line count and of 89.74 for that of the right side, which, considering the number of specimens, would seem to be a significant difference, again favoring the right side. However, for 300 specimens for Tippecanoe Lake, Indiana, he gave a higher average for the left side (87.69 as compared with 87.45).

The modified scales that form the large plates along the dorsal and anal bases of *Zeus faber* differ in number somewhat oftener than not on the two sides (Table XV), but the counts are higher on the one side almost exactly as often as on the other. The data, from Byrne (1902), were also treated by Duncker (1904:564-567, 647, 652) and Ludwig (1932:6).

A nearly constant asymmetry in an epidermal plate in the desert tortoise, *Gopherus agassizii*, was mentioned by Grant (1936:225). He stated that the left gular plate is the better developed in 331 out of 366 specimens. This relation holds true in several specimens examined by Norman Hartweg and us.



*Gill slits in hagfish.* — One of the most noteworthy bilateral differences in countable characters, that of the number of external gill openings in *Polistotrema stouti*, escaped the notice of Ludwig (1932). The count is asymmetrical in about one sixth of the specimens, and in these the openings are more numerous on the left side nearly twice as often as on the right (Worthington, 1905: 628–633; counts summarized and analyzed in our Table XV). The bilateral difference in number of gills was found to be somewhat less extreme, for the last or supernumerary opening in eleven fish was accompanied by a remarkably reduced gill or by no gill.

*Rostral teeth of sawfishes.* — Bilateral variation occurs with very high frequency in the number of teeth along the two edges of the rostral blade of the sawfishes (genus *Pristis*). Out of 84 specimens of at least three species from various localities 48, or 57 per cent, had 1 to 3 teeth more on one side than the other (Table XV). The count was higher on the left in 20 and on the right in 28. The difference in laterality is not reliable ( $P = 0.31$ ), and the data are vitiated by their diversity. Large series of counts for single species at one locality are needed. Some of our data were kindly furnished by Leonard P. Schultz and by J. L. Baughman.

*Pharyngeal teeth of Cyprinidae.* — In many minnows the pharyngeal teeth of the main row on the two arches slide together to form a cutting mechanism. In several European species the teeth mesh in such a way that the number is higher on one side, usually the left, than on the other (von Siebold, 1863: 172, 189, 214, 223, 227, 232, 236). The preponderance of higher counts on the left varies considerably (Table XVI), and most species have the same number on both sides. *Tinca tinca* is said to have commonly four or five on either side (von Siebold, 1863: 107). Subsequent discussions of bilateral asymmetry in cyprinid dentition, for example, those of von Martens (1896: 10) and Ludwig (1932: 230), are obviously based on von Siebold's account. The later authors compared the asymmetrical dentition of cyprinids with the similar arrangement of hinge teeth which occurs, with very uncommon reversals, in the shells of bivalve molluscs (for references and for data on the asymmetries in freshwater mussels see van der Schalie, 1936).

Like asymmetry has been found to characterize most, and probably all, American Cyprinidae (chiefly western) in which the pharyngeal teeth of the main row commonly vary from four to five.

TABLE XVI

BILATERAL ASYMMETRY IN NUMBER OF PHARYNGEAL TEETH IN  
CYPRINID FISHES

For source of data see text.

|                                                            | N   | L  | R | $\frac{100 (L + R)}{N}$ | $\frac{100 R}{L + R}$ | 100 P |
|------------------------------------------------------------|-----|----|---|-------------------------|-----------------------|-------|
| European species                                           |     |    |   |                         |                       |       |
| Hybrid, " <i>Abramidopsis</i><br><i>Leuckartii</i> " ..... | 45  | 24 | 0 | 53                      | 0                     | 0.00  |
| <i>Leucaspis delineatus</i> .....                          | 36  | 31 | 0 | 86                      | 0                     | 0.00  |
| <i>Rutilus rutilus</i> (4 races) .....                     | 104 | 79 | 0 | 76                      | 0                     | 0.00  |
| <i>Telestes agassizii</i> .....                            | 72  | 38 | 2 | 49                      | 6                     | 0.00  |
| <i>Phoxinus phoxinus</i> .....                             | 51  | 45 | 2 | 92                      | 4                     | 0.00  |
| <i>Chondrostoma</i> (3 species) ...                        | 95  | 10 | 1 | 12                      | 9                     | 2     |
| Western United States species                              |     |    |   |                         |                       |       |
| <i>Gila orcuttii</i> (a) .....                             | 40  | 38 | 0 | 95                      | 0                     | 0.00  |
| Hybrids (a $\times$ b) .....                               | 40  | 31 | 1 | 80                      | 3                     | 0.00  |
| <i>Siphateles mohavensis</i> (b) ...                       | 40  | 10 | 0 | 25                      | 0                     | 0.4   |
| <i>Siphateles obesus obesus</i> ...                        | 47  | 33 | 0 | 70                      | 0                     | 0.00  |

As a general rule, to which individuals but not species form exceptions, the higher number is on the left side when the count is asymmetrical. Supporting statistical data are not available for most species, but have been given by Snyder (1917: 62) for *Siphateles obesus obesus* and by Hubbs and Miller (1943: 356) for *Gila orcuttii*, *Siphateles mohavensis*, and hybrids between these species. These data are also analyzed in Table XVI.

*Crossing of optic nerves.* — The left-right relations in the decussation of the optic nerves of flatfishes have already been referred to (pp. 234-236). Some families of flatfishes and all fishes of other orders have a dimorphic chiasma, for either the left or the right nerve may be the more dorsal in the chiasma (in the Pisces there is no intermingling of the fibers where the nerves cross). Parker's counts (1903: 222-224) of one hundred specimens of each of ten species led him to conclude that there is no significant difference in the number of individuals with the left nerve or the right nerve the more dorsal. Larrabee's more intensive research (1906), however, proved that the right nerve of the brook trout (*Salvelinus fontinalis*) and the cod (*Gadus morhua*) is on top somewhat oftener than is the

left nerve. The differences, though proportionately small, are quite reliable statistically (Table XVII). The mathematical significance of the difference seems not to have been appreciated by Ludwig (1932: 232-234). Whether the other species studied have the nerve of one side dorsal the more frequently cannot be stated with assurance, for one hundred counts of each are insufficient for the

TABLE XVII

BILATERAL VARIATION IN LOCATION OF OPTIC NERVES IN CHIASMA OF  
ESSENTIALLY SYMMETRICAL FISHES

All data for *Salvelinus* and most of those for *Gadus* are from Larrabee (1906); all other material is from Parker (1903). Specimens with the left or the right nerve the more dorsal are listed under *L* or *R*, respectively.

|                                     | N     | L     | R     | $\frac{100(L+R)}{N}$ | $\frac{100R}{L+R}$ | 100 P |
|-------------------------------------|-------|-------|-------|----------------------|--------------------|-------|
| <i>Salvelinus fontinalis</i> .....  | 4,642 | 2,057 | 2,585 | 100                  | 56                 | 0.00  |
| <i>Fundulus majalis</i> .....       | 100   | 51    | 49    | 100                  | 49                 | 84    |
| <i>Menidia menidia notata</i> ..... | 100   | 61    | 39    | 100                  | 39                 | 3     |
| <i>Poronotus triacanthus</i> .....  | 100   | 53    | 47    | 100                  | 47                 | 55    |
| <i>Pomatomus saltatrix</i> .....    | 100   | 43    | 57    | 100                  | 57                 | 16    |
| <i>Stenotomus chrysops</i> .....    | 100   | 49    | 51    | 100                  | 51                 | 84    |
| <i>Tautoglabrus adspersus</i> ..... | 100   | 43    | 57    | 100                  | 57                 | 16    |
| <i>Tautoga onitis</i> .....         | 100   | 45    | 55    | 100                  | 55                 | 32    |
| <i>Prionotus carolinus</i> .....    | 100   | 53    | 47    | 100                  | 47                 | 55    |
| <i>Gadus morhua</i> .....           | 1,152 | 471   | 681   | 100                  | 59                 | 0.00  |
| <i>Melanogrammus aeglefinus</i> ..  | 100   | 48    | 52    | 100                  | 52                 | 69    |

determination of this point. Larrabee demonstrated that no significant differences in the offspring resulted when specimens of brook trout and cod with the left and the right nerve the more dorsal were mated in different combinations. For this reason we have tabulated as a unit all of his data for each species.

*Proportional measurements.*— Little effort has been made to determine whether bilateral differences exist in the body dimensions of the essentially symmetrical fishes (constituting all groups other than the Heterosomata or flatfishes). The only thorough test of this sort relating to parts not known to be asymmetrical was made by Duncker (1900: 562-564, 647, 651). His data, referring to the length of the head and of the mandible on the two sides of *Acerina cernua*, were reviewed by Ludwig (1932: 6-7), who regarded these

parts as symmetrical. The measurements were probably not expressed very precisely, for the indicated percentage of asymmetry is only 20 and 27, respectively, for the head and the mandible. When the measurements were bilaterally asymmetrical the head was more frequently the longer on the left side, the mandible more frequently the longer on the right. The differences, however, prove on the  $\chi^2$  test to be of very low reliability (Table XV).

Significant differences between the relative lengths of the lowermost pectoral ray on the two sides have been demonstrated for cottoid fishes (pp. 266-272 and 274).

*Coloration in a larval eel.* — One interesting case of bilateral asymmetry in coloration has been recorded for a fish in which the body and eyes are symmetrical. The postlarvae of an eel, known as *Leptocephalus diptychus*, are marked on each side by a row of conspicuous spots, which alternate in position, though all are clearly seen from both sides of the transparent ribbon-like body. In both specimens the spots number three on the left side and four on the right (Eigenmann and Kennedy, 1901).

#### ASSOCIATION OF SEX WITH BILATERAL ASYMMETRIES IN FISHES

The question has arisen whether the left-and-right asymmetries of fishes are correlated in any way with sex. There is considerable evidence that the proportion of left-handedness differs in males and females of the human species (Ludwig, 1932; Wile, 1934). The published data are conflicting, and some workers claim that the apparently greater incidence of left-handedness in human males is the result of social factors. Ludwig, however, concluded (p. 311) that 4 to 5 per cent of human adult males are left-handed, and that the percentage is only about half as large in adult females.

The original data for pectoral rays in *Leptocottus armatus* and for pectoral and pelvic rays in *Cyprinodon nevadensis*, and Duncker's data for pectoral rays in *Acerina* and *Syngnathus* and for pectoral rays and three other characters in *Platichthys flesus*, all referred to previously, are available for a test of the association of sex with bilateral asymmetry in fishes (Table XVIII). The frequencies for the two sexes are not certainly different for any character, but give some evidence of being different, especially for the pectoral rays. In some species the males are indicated as possibly the more sinistral, in others the more dextral, in respect to number of pectoral rays.

TABLE XVIII

## ASSOCIATION OF SEX WITH BILATERAL ASYMMETRIES IN FISHES

Counts higher on the left or the right side are listed under *L* or *R*, respectively. Significance of association is determined by the  $\chi^2$  test ( $\chi = t$ ).

|                                     | <i>N</i> | <i>L</i> | <i>R</i> | <i>t</i> | 100 <i>P</i> | Males *  |
|-------------------------------------|----------|----------|----------|----------|--------------|----------|
| Pectoral rays                       |          |          |          |          |              |          |
| <i>Leptocottus armatus</i>          |          |          |          |          |              |          |
| Males .....                         | 839      | 62       | 120      | 1.30     | 19           | <i>L</i> |
| Females .....                       | 814      | 40       | 106      |          |              |          |
| <i>Acerina cernua</i>               |          |          |          |          |              |          |
| Males .....                         | 650      | 65       | 49       | 1.23     | 22           | <i>L</i> |
| Females .....                       | 1,000    | 92       | 93       |          |              |          |
| <i>Syngnathus typhle</i>            |          |          |          |          |              |          |
| Males .....                         | 202      | 19       | 46       | 1.43     | 15           | <i>R</i> |
| Females .....                       | 362      | 31       | 45       |          |              |          |
| <i>Cyprinodon nevadensis</i>        |          |          |          |          |              |          |
| Males .....                         | 857      | 132      | 102      | 1.48     | 14           | <i>R</i> |
| Females .....                       | 853      | 128      | 74       |          |              |          |
| <i>Platichthys flesus</i> (dextral) |          |          |          |          |              |          |
| Total rays                          |          |          |          |          |              |          |
| Males .....                         | 562      | 5        | 351      | 1.93     | 5            | <i>R</i> |
| Females .....                       | 497      | 12       | 310      |          |              |          |
| Branched rays                       |          |          |          |          |              |          |
| Males .....                         | 528      | 2        | 516      | 1.36     | 17           | <i>L</i> |
| Females .....                       | 486      | 0        | 476      |          |              |          |
| Pelvic rays                         |          |          |          |          |              |          |
| <i>Cyprinodon nevadensis</i>        |          |          |          |          |              |          |
| Males .....                         | 888      | 146      | 130      | 0.42     | 67           | <i>L</i> |
| Females .....                       | 911      | 155      | 148      |          |              |          |
| <i>Platichthys flesus</i> (dextral) |          |          |          |          |              |          |
| Total rays                          |          |          |          |          |              |          |
| Males .....                         | 559      | 6        | 19       | 1.22     | 22           | <i>R</i> |
| Females .....                       | 497      | 14       | 22       |          |              |          |
| Branched rays                       |          |          |          |          |              |          |
| Males .....                         | 558      | 17       | 222      | 0.28     | 78           | <i>L</i> |
| Females .....                       | 496      | 14       | 203      |          |              |          |
| Extent of lateral line              |          |          |          |          |              |          |
| <i>Platichthys flesus</i> (dextral) |          |          |          |          |              |          |
| Males .....                         | 480      | 71       | 141      | 0.94     | 35           | <i>R</i> |
| Females .....                       | 544      | 84       | 138      |          |              |          |
| Side bearing eyes                   |          |          |          |          |              |          |
| <i>Platichthys flesus</i>           |          |          |          |          |              |          |
| Males .....                         | 602      | 40       | 562      | 0.21     | 83           | <i>L</i> |
| Females .....                       | 518      | 20       | 498      |          |              |          |

\* In this column *L* indicates that the males appear to be more sinistral and *R* that they may be more dextral than the females in the given character.

This association of sinistrality and dextrality with sex, if it actually exists, is not related to the differential development of the fins in the species as a whole.

#### SEXUAL RIGHTS AND LEFTS

In the literature on bilateral asymmetry reference has frequently been made to the "sexual rights and lefts" of *Anableps*. This is a genus of surface-swimming viviparous cyprinodont fishes still more famous for the division of the eye into two parts, one adapted for aerial vision and one for subaqueous vision.

These statements regarding sexual rights and lefts in *Anableps* rest on the accounts by Garman (1895a: 73-74, pl. 7; 1895b: 1012-1013, figs. 1-4). In monographing the Cyprinodontes this author discovered that the structure of the gonopodium (a highly modified anal fin) of *Anableps* adapts it more for sidewise than for vertical motion, and that this intromittent organ appears to be functionally effective toward the left in some males, toward the right in others. He also observed that the oviducal opening of the female is covered either by an enlarged scale (the "foricula"), which opens along either its left or right edge, or, in one species, by several scales which open on one side of a groove. Garman assumed that mating can occur only between dextral males and sinistral females and vice versa. This was a logical deduction but remains to be proved. The theory that the males always mate from one side only is hardly consistent with the equal development on the two sides of the spiny contact organs on the scales.

Garman stated that nearly three fifths of the males are dextral, and two fifths sinistral, whereas the females exhibit the reversed ratio (about three fifths sinistral and two fifths dextral). He thought that these ratios confirmed his theory that only rights can mate with lefts, and lefts with rights. Garman's data, however, were scarcely adequate. His ratio of counts of lefts to rights for the males was 6:11 for *Anableps anableps* and 8:14 for all three species; for the females, 34:21 for *A. anableps* and 36:23 for all species. In specimens at hand the left-right ratios are as follows: for *A. anableps* males, 0:1; for *A. dowei* males, 2:3; for *A. dowei* females, 3:1. These counts added to Garman's are analyzed for the three species combined (Table XIX). The deviation of the ratios from equality may be rated as probable but not dependable.

TABLE XIX

## ANALYSIS OF SEXUAL LEFTS AND RIGHTS AMONG FISHES

External structures only are considered. For source of data see text.

|                                                                                          | N    | L    | R   | $\frac{100(L+R)}{N}$ | $\frac{100R}{L+R}$ | 100 P |
|------------------------------------------------------------------------------------------|------|------|-----|----------------------|--------------------|-------|
| Genital opening on left (L) or right (R) side in <i>Anableps</i>                         |      |      |     |                      |                    |       |
| Males .....                                                                              | 28   | 10   | 18  | 100                  | 64                 | 19    |
| Females .....                                                                            | 63   | 39   | 24  | 100                  | 38                 | 9     |
| Concavity on left (L) or right (R) side of gonopodium of males                           |      |      |     |                      |                    |       |
| <i>Poeciliopsis</i> and <i>Poeciliates</i> (various species, Mexico and Guatemala) ..... | 400+ | 400+ | 0   | 100                  | 0                  | 0.00* |
| <i>Allophallus kidderi</i> .....                                                         | 164  | 0    | 164 | 100                  | 100                | 0.00  |
| Unnamed genus, Guatemala .....                                                           | 277  | 0    | 277 | 100                  | 100                | 0.00  |
| Xiphophorini (7 species) .                                                               | 365  | 182  | 183 | 100                  | 50                 | 100   |
| <i>Gambusia affinis affinis</i> ...                                                      | 353  | 179  | 174 | 100                  | 49                 | 84    |
| <i>Dermogenys pusillus</i> .....                                                         | 80   | 36   | 44  | 100                  | 55                 | 37    |
| Location, left (L) or right (R), of aroctal side of males of Phallostethidae             |      |      |     |                      |                    |       |
| <i>Phenacostethus smithi</i> ....                                                        | 334  | 155  | 179 | 100                  | 54                 | 19    |
| Asymmetries in females of <i>Horaichthys</i>                                             |      |      |     |                      |                    |       |
| Location of genital pore, on midline or to left (L) or right (R) † .....                 | 210  | 126  | 42  | 80                   | 25                 | 0.00  |
| Presence of pelvic fins on both sides or only on left (L) or right (R) .....             | 210  | 205  | 0   | 98                   | 0                  | 0.00  |

\* A 100 P value of 0.00 indicates that the odds are less than 1 in 20,000 that the result obtained is due to chance.

† Approximate figures, obtained from Kulkarni's statement that in about 210 females the genital pore was on the left side in about 60 per cent, on the right side in 20 per cent, and on the median line in the rest.

Naturally little significance can now be attributed to Garman's theory about the rôle of selection in the origin and in the possible future changes of these left-right relations in the sexes of *Anableps*.

Nor can much credence be placed in his theory (1896:232) that the sexual rights and lefts of *Anableps* were evolved to prevent close inbreeding between fish that swim habitually in pairs, side by side. In the first place, according to our observations, the various surface-swimming cyprinodonts commonly move in small groups, and there is no reason to believe that they pair off at any time other than when they are actually spawning. The idea that the pairs continually swim together seems to have stemmed from a fancy which Agassiz expressed when he applied the name *Zygonecles*, meaning "yoke swimmer," to the surface-swimming forms of *Fundulus*. In the second place, it is not to be expected that sibs would be any more uniformly rights or lefts than are more distant relatives. A more plausible theory is that the one-sided structure of the sex organs makes possible the completion of the copulatory act while the pair maintains the surface-swimming position for which *Anableps* is marvelously adapted. On the basis of recent work on sex recognition and breeding habits in fishes it seems probable that a male *Anableps* will attempt to mate with any other individual of the species, but will complete the act only with females and perhaps only with females having the opposite turn to the sex organs.

Garman's treatment of sexual rights and lefts in *Anableps* has been reviewed and discussed by numerous authors, including von Martens (1896:8-9), Meisenheimer (1921:166-167), and Ludwig (1932:230-231). Von Martens compared the two types of *Anableps* adults with the sexual rights and lefts of gastropods. Ludwig wrongly included *Zygonecles* among the South American genera in which the sperm duct penetrates the anal fin.

Garman wrote of "an allied genus of the family" in which the males only are modified into rights and lefts. He referred to *Jenynsia*, now classed in a separate family. Langer (1913:208-210) also discussed the question of rights and lefts in *Anableps* and *Jenynsia*, and stated that a male of *Jenynsia lineata*, which he observed, consistently mated to the right.

Sexual rights and lefts may also be distinguished among the Poeciliidae, the most speciose family of cyprinodont fishes. In some species we have noted that the fleshy structures connected with the oviducal openings are consistently directed toward one side. More definite bilateral asymmetries, in certain genera, characterize the gonopodium of the males (this is the intromittent organ, a modified



anal fin). In the Poeciliopsinae this structure is folded to form a tube along one side: on the left side in most genera; on the right side in *Allophallus* (and in another, unnamed genus from Guatemala); and on either side in *Xenophallus* (Hubbs, 1936: 232-235). Statistical data have now been gathered to fortify these observations (Table XIX). Unfortunately, no adequate material is at hand by which to determine the ratio of rights to lefts for *Xenophallus*.

Sexual rights and lefts may also be distinguished among the poeciliid fishes in which the gonopodium is not folded to form a rigid tube. In the tribe Xiphophorini, for example, rays 3 and 5 of the anal fin in the adult male are more or less pulled toward each other to form a broad groove. As a result the deep trough of ray 5, along the fundamentally posterior edge of the gonopodium, is twisted toward the same side. The last anal rays are directed toward the opposite side. In this group as many males have the gonopodium concave on the left side as on the right. This was found to hold true for all seven species in the tribe, namely *Platypoecilus couchianus*, *P. xiphidium*, *P. variatus*, *P. maculatus*, *Xiphophorus montezumae*, *X. pygmaeus*, and *X. hellerii*. The consistent data for all the species were consolidated for presentation in Table XIX.

*Gambusia*, taken as an example of the many poeciliids which have the gonopodium proper rather rigidly fixed in one plane, is also indiscriminate in the laterality of the intromittent organ (Table XIX). In this genus only a trace of concavity is appreciable on either side of the gonopodium, but the short posterior rays are fluted, with the major concavity on either the left side or the right. In perhaps 10 per cent of the specimens examined the allocation into rights and lefts was more or less arbitrary, either because the concavity was very shallow or because of a doubly sigmoid curvature of the posterior rays.

Apparently the fixation of the concavity on one side of the gonopodium in the Poeciliidae was correlated with the elaboration of the trough into a definite tube.

There is some evidence to indicate that the poeciliids customarily copulate from one side. Philippi (1908: 17) stated that among dozens of males of "*Glaridichthys januarius*" (= *Phalloceros caudimaculatus*) which he had observed all except four, which were reversed in this respect, swung the gonopodium to the left. Out of about twenty-five males of "*Glaridichthys decem-maculatus*" (= *Cnesterodon decem-*

*maculatus*) all copulated to the right, except three which moved the gonopodium to the left. Langer (1913:214) indicated that the morphology of the gonopodium made movement to the one side easier in these two poeciliids. Ludwig (1932:230-231), quoting Meisenheimer (1921:167) as a secondary authority, also stated that copulating usually to the left or to the right in these two cyprinodonts is correlated with the asymmetrical structure of the gonopodia. These organs in *Phalloceros* and *Cnesterodon* are nearly symmetrical and form no definite tube, but the posterior rays are curved to one side and movement of the sexual organ appears, at least in preserved specimens, to be easier toward one side (toward the right in the single male of each genus at hand). The indicated correlation between bilateral asymmetries in reproductive habits and in secondary sexual structures, in these and other viviparous cyprinodonts, calls for further inquiry.

Sexual rights and lefts also occur among the viviparous half-beaks, Indo-Pacific fishes hitherto placed in the Hemiramphidae but more satisfactorily classed in a separate family, Dermogenyidae. In certain species of *Zenarchopterus* an enormously enlarged anal ray lies on either the left or the right side of the fin. In *Z. brevirostris* this ray lies to the left in three specimens, to the right in six (Mohr, 1926:253, fig. 15). In *Z. xiphophorus* it is on the left side of the fin in one fish, on the right in three (Mohr, 1934:11-12, fig. 2). We find that the rather elaborate gonopodium of *Dermogenys*, described in detail by Mohr (1936), is likewise either sinistral or dextral. On either the left or the right side the first three rays of the four-rayed gonopodium are folded to form a groove, which is partly enclosed by a fleshy process arising from the membrane between the third and the fourth rays. In eighty males of *Dermogenys pusillus* from various parts of Java, collected in 1929, the tube thus formed lies on the left side in thirty-six specimens and on the right in forty-four (Table XIX). The slight preponderance of dextral males in these data is not dependable statistically.

The males of the family Phallostethidae comprise individuals that are known to be rights and lefts in respect to mating behavior as well as structure. The complex clasping organ or priapium of these remarkable Asiatic fishes is asymmetrical in that, for example, the anus opens on the "proctal" side and the ctenactinia arise on the opposite or "aproctal" side. That the proctal and aproctal

sides are either right or left has been observed in all the main treatises on the phallostethids (Regan, 1916: 5, 23; Myers, 1928: 5; Villadolid and Manacop, 1934: 200; Bailey, 1936: 453; Aurich, 1937: 264, 266, 275, 282; Herre, 1942: 139). Villadolid and Manacop observed that a given male always clasps a female from the same side. Aurich showed for certain species that the asymmetry involves the rudimentary pelvics of the males, before these fins lose their obvious identity in the organization of the priapium. Since no statistical data have been published to itemize how "indiscriminate" the laterality of the priapium is, we have made counts of the side that is aproctal in 334 males of *Phenacostethus smithi* Myers, all collected by Hugh M. Smith at Bangkok, Siam (Thailand). This side was found to be left in 155 fish and right in 179 (Table XIX). The deviation from equality is not very reliably significant ( $\chi^2 = 1.72$ ;  $P = 0.2$ ).

In another bizarrely specialized Asiatic fish, *Horaichthys setnai*, bilateral asymmetries (Table XIX) are associated with clasping (Kulkarni, 1940). In this cyprinodont the females are usually lefts, in the sense that the oviduct opens to the left of the median ventral line in about 60 per cent of the individuals and to the right side in only 20 per cent (Kulkarni, 1940: 401). A much more remarkable asymmetry in this fish is the almost invariable lack of the right pelvic fin in the female. Ordinarily, no trace could be found of either the right pelvic or its basal bone, at any stage of development. An adaptation seems to be involved (Hubbs, 1941b: 447), for the lack of the one fin provides the integumentary surface, opposite the oviduct, that is needed for the attachment of the spiny-headed spermatophore of this weird little fish.

Another very striking bilateral asymmetry associated with reproduction has been discovered recently in an unnamed cyprinodont genus from Guatemala. One of the several unique characteristics of this fish is the development on one side only of a structural complex to which a clasping function is obviously to be ascribed. The upper edge of the pectoral fin is transformed into an elaborate system of hooks and spines, and the scales on the base of the fin are enlarged and hardened to form a stiff plate with a free edge. In the single mature male collected it is the right fin that is so modified. The left pectoral is essentially normal, for it shows scarcely a trace of the bizarre specialization of the opposite member. Incidentally,

since Garman brought up the comparison, we might remark that in one respect this fish corresponds much more closely than *Anableps* with the fanciful *jaftak* of Persian literature, "a sort of bird that is said to have but one wing, on the opposite side to which the male has a hook, and the female a ring, so that when they fly they are fastened together." The female of the Guatemala poeciliid, however, shows no apparent modification which could be correlated with the clasping device of the male.

#### BILATERAL ASYMMETRY OF RAYS

To some extent in many fishes, most notably in breeding males which have fins that are modified for clasping or copulation, the two halves of certain soft rays lose their complete bilateral symmetry. This is spectacularly true of cyprinid fishes, in which the pectoral fin of the breeding male is enlarged and thickened and bears nuptial tubercles on the inner surface. In *Rhinichthys atratulus*, for example, the basal part of the main pectoral rays is very different on the two sides. The upper hemitrichia (phyletically the left halves of the rays on the left fin and the right halves on the right fin), as compared with the lower hemitrichia, are ribbon-like instead of cylindrical, lack the posterior keel that is developed on the other side, have the segments fused farther outward, and have their origins much farther back along the base of the fin.

In adult males of *Gambusia* the "dorsal components" of rays three to five of the pectoral fin remain slender, while the "ventral components" of the same rays become greatly dilated (Turner, 1942: 394). These components are the left and the right halves of the rays, but the bilateral relations have become reversed during the evolution of the fin. What is now the right, dorsal, inner face of the left fin was the left, outer, surface when the fin held its primordial fin-fold position. What is now the right half of each fin of the more advanced teleosts was originally the left side; what is now inner was then outer.

In the adult males of the Poeciliopsinae the detailed structure of the left and right elements of certain rays of the gonopodium are strikingly different (Hubbs, 1924: 26, pl. 2; 1926a: 63, 68; 1936: 233-235). In *Pamphorichthys minor* an even more remarkable bilateral asymmetry of a soft ray is manifested: on the left side the second pelvic ray retains the usual rodlike form, but on the right

side three subterminal segments are expanded into strong bispinous processes. This discovery was made by Luis Howell Rivero, whose unpublished drawing we reproduce, with thanks, as Figure 2.

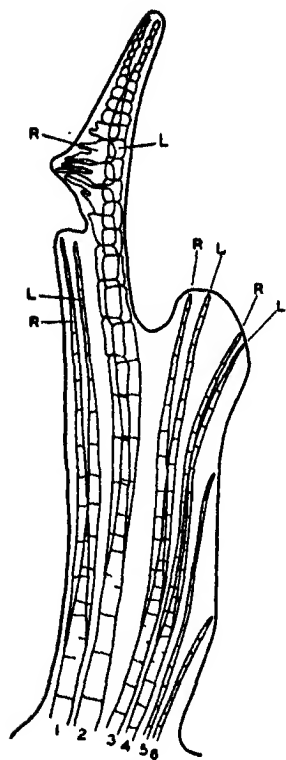


FIG. 2. Right pelvic fin of *Pamphorichthys minor*, showing the bilateral asymmetry of ray 2. Drawing by Luis Howell Rivero

The pectoral fins usually show some asymmetry between the left and right elements of each ray, particularly in the basal region of attachment, in correlation with the shift of the pectoral base from a longitudinal axis and ventral location to a vertical axis and lateral position. The outer and inner halves of the pectoral rays bear very different structural relations to the body. In the dorsal and anal fins the right and left sides of the spines (which, unlike the soft rays, are median unpaired structures) are somewhat dissimilar when the spines are heteracanthous, that is, when alternate spines are directed to right and to left. These asymmetries are not confined to breeding males.

Thus small parts of the body which have a bilaterally paired structure, or which merely have right and left sides, may develop bilateral asymmetry comparable to the dissimilarities between halves of the organism. When the bilaterally paired pectoral fins show such asymmetry within the ray structures, the direction of asymmetry is reversed on the two sides of the body, and each fin

as a whole becomes the mirror image of the other. The spatial sequence of asymmetry is correlated with the general asymmetry of the fin, for the outer half of each ray differs from the inner half in the same way, whether either half be (fundamentally) left or right. This relation recalls the secondary asymmetries of the flatfish, in which the direction of asymmetry is correlated with the general asymmetry of the body, not with rightness or leftness as such.

## GENERAL INTERPRETATIONS AND CONCLUSIONS

On the foregoing pages we have presented a considerable body of new evidence indicating that the right and the left sides of fishes are not exact mirror images of each other. Previous findings that point to the same conclusion are reviewed. Both the new and the old data have been subjected to statistical test, to appraise the trustworthiness of the information. Some suggestions have been made toward an explanation of certain of the observed differences between the sides. In the following sections the observations are further integrated, and the interpretations are brought to bear on certain problems of general biology.

## EXTENT OF BILATERAL ASYMMETRIES

Some degree of difference between the left and right elements of bilaterally paired structures may now be said to be of frequent occurrence among fishes. Particularly notable asymmetries, involving locomotion as well as structure, characterize the Cephalochordata — the highly modified derivatives of the ancestors of the fishes (Ludwig, 1932: 222-224). Marked differences between the sides occur in the gill region of the Marsipobranchii, which are at once the most primitive and among the most specialized of the fishes (p. 284 and Ludwig, 1932: 230). Among the more typical fishes many bilateral asymmetries occur, some of which are common to all the vertebrates (Ludwig, 1932: 224-228, figs. 109-110), whereas others are peculiar to fishes as a whole or to particular groups of fishes. The special asymmetries recorded through this treatise characterize many of the Pisces, both primitive and specialized.

The differences between the sides are best known and most strikingly displayed in the flatfish order (Heterosomata), but are by no means confined to that group. Some of the bilateral dissimilarities of the flatfishes are unrelated to the major asymmetry of the eyes and color, but numerous other differences between the sides are definitely correlated with the position of the eyes. Reversal of the sides involves only the latter set of asymmetries. Among the bilateral differences that are correlated with eyedness or blindness rather than with leftness or rightness as such are those that involve the number of rays in the paired fins. As a general rule, the fin of the blind side is the less developed.

Not only in the flatfish order but also among fishes in general bilateral asymmetries appear in all parts of the body, superficial as well as internal. Average differences between the paired fins, particularly as measured by the number of rays, seem to be frequent. Other asymmetries are exhibited in the folding of the branchiostegal membranes; in the number of branchiostegal rays; in the number of gill slits in a hagfish; in the teeth; in the crossing of the optic nerves; and in many other characters. Asymmetries in sexual structures produce sexual rights and lefts. Even fin rays may show differences between the left and the right rows of segments.

Bilateral differences thus characterize all groups of fishes and appear in many structures.

#### FACTORS DETERMINING BILATERAL ASYMMETRIES

Why the two sides of fishes differ from each other is a question which has never been adequately answered, and it seems doubtful that any simple, general explanation will be forthcoming. Some students of the problem have theorized that the asymmetries in the adult may be traced to a reversal of the flexure or the structure in the embryo or egg. The data on the flatfishes go far to negate this idea, for reversal of the eyes is correlated with only certain of the other bilateral differences — except in the single specimen which we interpret as completely reversed.

This lack of correlation between different asymmetries in the flatfishes and the independent manifestation of different asymmetries in teratological flatfishes which show a partial return toward symmetry are among the facts which lead us to conclude that a multitude of factors is involved in the asymmetry of the Heterosomata, and that the whole genetic and developmental mechanism has been keyed together to produce animals with sides as unlike as are those of the flounders. We think that this conclusion applies also to fishes other than the exceedingly asymmetrical Heterosomata.

The large degree of independence that seems to exist between the factors responsible for asymmetries in fishes may be regarded as an example of a general phenomenon. Simple cause-and-effect relations, particularly those that call for many consequences of some one developmental factor, are often easier to assume than to prove or confirm, and often fail to meet critical tests. Thus it has been proved by researches on dogs that the different symptoms of achon-

droplasia, though ordinarily associated with one another and related to the same endocrines, are caused in large part by independent genetic factors which are capable of being separated by appropriate genetic tests (Stockard, 1941).

That there is no consistent favoring of either the left or the right side is indicated by the facts: (1) that many structures show in different groups the same bilateral asymmetry, except for a 180° change in direction; (2) that many of the known asymmetries are subject to such reversal by individual variation; and (3) that individuals may be sinistral in some characters, dextral in others. Among individuals with a different ray count in the two pectoral fins the right count may be the higher more frequently in some species, the left count the higher more frequently in others. This contrast may even be shown by different species within one group. One family of flatfishes has the eyes and color on the left side, another is eyed and colored on the right side; and in each group individual reversals occur, rarely in most species but very commonly in others. There is little evidence of correlation between the sidedness of the pectoral and the pelvic fins.

In general, it appears to be of little concern to an animal whether the right side or the left side is better developed. As Sumner and Huestis (1921: 445) have pointed out, structural changes in the anterior-posterior and the dorsal-ventral axes would seriously modify the environmental relations and welfare of an organism, but reversal in bilateral asymmetries has no such fundamental significance. It would appear that sinistrality and dextrality as such have little or no effect on an animal's chance for survival and reproduction. It is therefore easy to understand why, in respect to certain characters, some species are sinistral and others dextral, still others, either sinistral or dextral, in a 50:50 proportion or in any other ratio.

Asymmetry in itself, without reference to which side is favored, can often be interpreted with high plausibility as of adaptive value. Thus asymmetries in internal organs make for a division of labor between the sides. A flounder lying flat on one side is in a favorable position to simulate the bottom and thus to escape recognition and possible destruction.

Environmental factors related to the earth's rotation may have some effect on asymmetrical form and growth in plants, but they seem wholly unrelatable to bilateral asymmetries in free-swimming



animals. Little credence can be placed in the theories (for instance, those discussed, some with favor, by Wile, 1934) that sinistrality or dextrality in animals is due to such factors.

#### BEARING OF BILATERAL DIFFERENCES ON SYSTEMATICS

Since many superficial as well as internal characters are often more or less different on the two sides, it is obviously a wise policy in systematic studies to count or measure given characters consistently on one side, or to study both sides. The danger of inconsistent attention to the sides is perhaps greatest in racial studies. Thus, if in a research on the races of king salmon one investigator were to count the branchiostegal rays on the left side for certain localities and another (or the same) worker were to enumerate the rays of the right side for other localities, the sharp bilateral differences (p. 280) would likely be misinterpreted as characters of geographical races.

It remains to be determined whether direction and amount of asymmetry are consistent enough through series of species or groups to be usually indicative of phyletic relationship. Examples can be cited of such consistency, for instance, in the general pattern of visceral asymmetry of large groups. Whether the right or the left optic nerve is uppermost in the chiasma is a prime distinction between two families of flatfishes (p. 235). But whether in general the type of bilateral asymmetry of given structures is of systematic significance is an unanswered problem.

#### RELATION TO PROBLEM OF HANDEDNESS IN MAN

Many of the theories of handedness, reviewed at great length in such books as those by Parson (1924), Ludwig (1932), and Wile (1934), presuppose that this phenomenon is peculiar to man, or that handedness in man is unrelated to the observed bilateral asymmetries of other animals. The immense scattered literature on the subject is turgid with religion, mysticism, antique folklore, vaporous philosophy, Lamarckism, a plethora of mere argumentation, and an endless series of semiscientific ideas based on totally inadequate data. Most authors, even those with biological background, stress the ambidexterity of lower animals and apes and the imperfect development of right-handedness in primitive and degenerate men, and look on the elaboration of dextrality as an accompaniment of

progressive human evolution. Geneticists are flirting with the odd theory that left-handed humans are the survivors of identical twins, of which the dextral partner has failed to develop.

A consideration of bilateral asymmetries in the lower vertebrates, particularly the asymmetrical development of the forelimbs, helps to remove human handedness from its isolated position, and to integrate this phase of human biology with general biology. Some fishes which show bilateral asymmetry in the forelimb can be said to be right-handed, but even in these species many individuals have the left limb better developed than the right. Other species, however, may be said to be left-handed as a rule. Much of the discussion of factors determining bilateral asymmetries (pp. 298-300) applies to the problem of right-handedness.

In some flatfishes, as in man, handedness is correlated with modifications of the central nervous system, and handedness in fishes as well as in *Homo sapiens* is undoubtedly inherited. Whether or not man's ancestors were ambidextrous (a debated question), there is no good reason to assume that right-handedness in our species is a peculiar or an isolated phenomenon. No reliable evidence was obtained to indicate that sinistrality or dextrality in fishes is associated with sex.

An appreciation of the biological naturalness of handedness in man should help to dispel remaining traces of the primitive folklore which associates right-handedness with righteousness and left-handedness with the sinister. It should also help to exclude from the realm of serious consideration the not infrequently held misconception of handedness as a purely cultural expression.

The prevalence of right-handed and left-handed conditions among the fishes removes the necessity for explaining human handedness on a specifically human basis, but does not preclude the possibility that right-handedness in man arose as an adaptation connected with the handling of tools or the wielding of weapons. There is particular plausibility in the frequently proposed idea that holding the shield on the vital left side and wielding the spear by the strong right arm were basically correlated with the sharp differentiation between the arms of man. It seems unlikely that these customs initiated right-handedness; it is more probable that through natural selection the differentiation of the arms may have been intensified and rendered more nearly universal.

## SUGGESTIONS FOR FURTHER RESEARCH

Several new lines of inquiry into the problem of laterality in fishes present themselves. An extensive statistical inquiry into the extent of the phenomenon is needed to understand the various correlations involved and to bring the data on asymmetry to bear on systematic problems. By focusing attention on the number of rays in the pectoral and pelvic fins, for example, we may learn whether dextrality and sinistrality are related to taxonomy, to shape or position of fin, to habitat, or to mode of life; whether symmetry or asymmetry is the usual condition; whether dextrality is more frequent than sinistrality in individuals and in species. Other lines of research are needed to determine whether locomotor or other functional asymmetries are involved.

By modern methods of physiological research it may be possible to determine whether there is a difference in the metabolic level of the two pectoral fins during the stage at which the number of fin rays and the relative length of the lowest ray are established. The oxidation-reduction pattern may be determinable by the vital stain method which has recently been used by Rulon (1935) and by Child (1942, 1943) in demonstrating the axial gradients in developing animals, including the fish *Oryzias*. In this way one might be able to test and analyze the correlations between differential metabolism and distinctive segment numbers, which have been suggested (as by Hubbs, 1926b) on largely theoretical grounds. The idea that available space is a main factor in determining the number of meristic elements (p. 268) can be put to test. In using paired structures of individual embryos or larvae one would largely eliminate many variables — such as the age, previous history, stage of development, and genetic constitution of the subject.

Perhaps sometime we shall learn by such studies why, for example, the pectoral fin in one race or species ordinarily forms fifteen rays, whereas this fin in a related kind of fish produces sixteen rays. An answer to this problem would materially advance our appreciation of the physiological fundamentals of speciation.

## SUMMARY

The left and the right halves of fishes are not perfect mirror images, for many of the organs are more or less unlike on the two

sides. Bilateral asymmetries affect all groups of fishes and appear in various organs, superficial as well as internal.

Duncker's index of asymmetry ( $\alpha$ ) confuses the amount and the direction of asymmetry. It seems better to express these factors separately, as the percentages of asymmetry and dextrality. The significance of the ratios of lefts and rights among the asymmetrical individuals is appraised by the  $\chi^2$  test, which leads to a probability estimate ( $P$ ).

The outstandingly asymmetrical vertebrates are the flatfishes (Heterosomata). *Psettodes* is the only genus that is indiscriminately dextral or sinistral, on a primordial basis. Some families are normally dextral, others sinistral; one family has both dextral and sinistral genera. Reversal of sides is generally very rare, but is common in a few species, chiefly of the North Pacific. There is some evidence that reversal is accompanied by a decrease in viability. Reversed flounders are not true mirror images of normal individuals, for asymmetries of the optic nerves, viscera, and branchiostegal membranes remain unaltered. Only one specimen, newly discovered, seems to represent a complete change-over of the sides, presumably because of some basic reversal in the embryo or egg. Ambicoloration is regarded as a teratological return toward symmetry, in which various asymmetries are differently combined and therefore appear to be due to independent genetic factors. Most asymmetries in flatfishes are associated with the location of the eyes and color on one side. As a general rule, the pectoral fin of the eyed side, whether right or left, has on the average more rays than does the fin of the blind side.

Many bilateral asymmetries also characterize the essentially symmetrical fishes. Thus the pectoral and pelvic rays may be more numerous on the right side oftener than on the left. In other species the left fin is more frequently better developed when the two are unlike. The number of rays appears to be determined by the size of the fin when the formation of rays is completed. In general, the number of meristic parts in a structure probably depends on the space that is available at the time when the formation of the countable parts is completed. The length of the lowermost pectoral ray measures the degree of development of the fin. As yet there is no reason to assume that there is any positive correlation between the pectoral and the pelvic fin in regard to the direction of bilateral asymmetry.

With some reversals in *Esox*, the left branchiostegal membrane overlaps the right in fishes having these membranes separate. In *Albula*, *Oncorhynchus*, and *Esox* the branchiostegal rays in the left membrane more or less consistently outnumber those of the right. The trustworthiness of bilateral differences in the scale counts of fishes remains to be proved. In a hagfish the gill openings on the left side are more numerous oftener than are those on the right. In cyprinid fishes with asymmetrical dentition the larger number of pharyngeal teeth usually occurs on the left arch. In *Salvelinus* and *Gadus* the right optic nerve is the more dorsal in the chiasma slightly oftener than is the left nerve.

There is no clear-cut evidence that bilateral asymmetries in fishes are associated with sex. Sexual rights and lefts involving bilateral differences in reproductive structures and habits characterize several genera of fishes. Differences also occur between the two sides of certain soft rays.

A multitude of independent but usually associated factors appears to be responsible for bilateral asymmetries — an example of a general biological principle. Because of the average differences between the sides it is desirable in systematic and racial studies to make the counts consistently on one side or to study both sides. Some patterns of asymmetry are consistent enough to be of taxonomic value, but how generally the amount and direction of bilateral asymmetries can be used as systematic characters is not now apparent.

The frequent occurrence of bilateral differences between the forelimbs and between the left and right elements of many other structures of fishes counters the widespread idea that handedness is a peculiarly human trait, or the result of training.

It may be possible, particularly through physiological studies, to correlate the degree of development and the metabolic characteristics of the embryonic pectoral fin with the number of rays that are formed. Such investigations may materially advance our understanding of the physiological fundamentals of speciation.

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Head region of normal and totally reversed specimens of  
*Tanakius kitaharae*

FIG. 1. Normal (dextral) specimen, 210 mm. in standard length,  
from Sea of Japan

FIG. 2. Reversed (sinistral) specimen, 220 mm. long, from off  
Onahama, Japan



PHARYNGEAL POCKETS IN THE GIZZARD  
SHAD, *DOROSOMA CEPEDIANUM*  
(LESUEUR) \*

KARL F. LAGLER

*University of Michigan*

AND

WALTER C. KRAATZ

*University of Akron*

INTRODUCTION

ALTHOUGH Hyrtl (1855, 1863) described and figured paired pharyngeal pockets in other clupeoid fishes, the present work is the first report of the occurrence of such structures in the gizzard shad, *Dorosoma cepedianum*. Their discovery in this fish was made by Kraatz while studying the food of the species in certain Ohio lakes. The descriptions by Hyrtl appear to constitute the only previous detailed research on these structures, which he called "*die accessorischen Kiemenorgane*" or "*die Kiemenschnecke*." Ridewood (1904) recognized their existence in his work on clupeoid osteology, and Bridge (1904) makes mention of them. Rauther (1910) summarized the occurrence of more or less comparable structures in the synbranchids, clupeoids, characinids, and other teleosts in his study of the accessory respiratory organs in bony fishes, but did little original work on the three families mentioned. We have examined several characins, however, and have failed to find the pockets.

It is the purpose of the present paper to describe the organ and to consider its possible function in the gizzard shad. Specimens examined and found to contain the structure were of both sexes and ranged in standard length from 18.8 to 261 mm.

The authors acknowledge with gratitude the assistance of Carl L.

\* Contribution from the Department of Zoology, University of Michigan, and from the Department of Biology, University of Akron.

Hubbs, Peter Okkelberg, Alfred H. Stockard, Kenneth H. Doan, and others who by contributing material or ideas have helped in this study. Translations of German references were made by Rosalie Lagler.

#### GROSS FEATURES

On raising the opercular bones on either side one may see the swelling of the lateral surface of the pharyngeal organ in the dorsal part of the area exposed (Pl. I, Fig. 1). It lies above the gills, just below the supratemporal and posttemporal and directly in front of the supracleithrum. The integument, which also covers the bones of the shoulder girdle, invests the structure laterally. Some muscularization of this superficial covering of the pockets is evident and may aid in their contraction.

The two pharyngeal pockets which compose the organ are paired; one lies on each side of the mid-line above the caudal part of the pharynx, but their mesial surfaces are not in contact with one another (Pl. I, Fig. 2). They are separated by a considerable space, which is only partly occupied by median and paired blood vessels. Each pocket constitutes an anteriorly extending diverticulum of the expanded chamber in the caudal roof of the pharynx, with which its lining is common and continuous. Innervation is by at least three principal branches of the vagus trunk on each side.

A more exact relation of the organ to the pharynx and to its supporting elements may be seen when it is viewed in parasagittal section, nearly midsagittal in position (Pl. I, Fig. 3). Posteriorly the pharynx extends dorsally and enlarges into a distinct chamber. The portals of the paired pouches and the esophagus lie near the highest level of this chamber, on approximately the same horizontal plane. The caudal opening into the esophagus is, of course, on the mid-line. The paired entries into the pharyngeal pockets are on either side and open cranially into the *entrance canals* of these structures.

Each pocket is chiefly supported by and attached to the greatly expanded epibranchial bone of the fourth gill arch, upon which it rests. The expansion takes the form of a lateral wing with lattice-like structure (Pl. II, Fig. 4; Text Fig. 1). Additional support and place for muscular attachment for the pharyngeal pocket are provided by a cartilaginous extension, which arises on the lateral edge of the

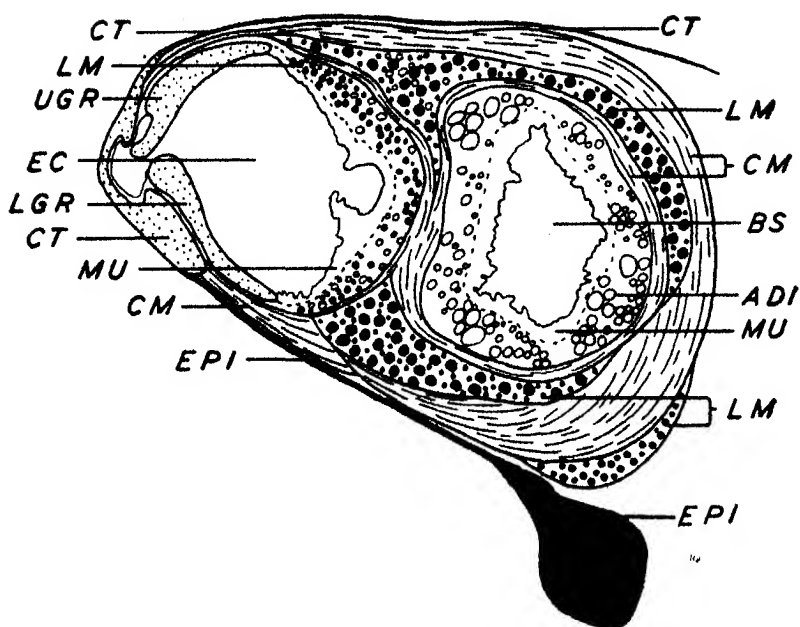


FIG. 1. Diagrammatic cross section of left pharyngeal organ of gizzard shad, viewed from behind. ADI, adipose and areolar connective tissue layer; BS, lumen of blind sac; CM, circular muscle bundles; CT, cartilaginous extension of epibranchial bone; EC, lumen of entrance canal; EPI, fourth epibranchial bone with lateral expansion; LGR, lower row of gill rakers in entrance canal (posterior row of fourth gill arch); LM, longitudinal muscle bundles; MU, mucosa and submucosa; UGR, upper row of gill rakers in entrance canal (anterior row of fifth pharyngeal arch). The magnification is about 8.9 diameters

bony expansion of the epibranchial. The cartilage exceeds the bone in area, and partly encapsulates the organ laterally (Pl. I, Fig. 2). Dorsally the cartilage leaves the organ and rises to terminate at the ventrolateral edge of the vertebral column. Its attachment to the vertebrae and adjacent body wall is by loose fasciae. The organ also lies somewhat upon dorsal branchial elements of other arches anteriorly and has some loose membranous attachment to the cranial base. This attachment is particularly to the region of the epiotics and to the keel-like ventral extension of the parasphenoid. The posteriorly directed angle and cartilaginous joint between the ceratobranchial and epibranchial of the fourth arch are supported by an



articulation with the dorsal prominence of the fifth ceratobranchial (the lower pharyngeal bone), which alone represents the fifth branchial arch on each side (Pl. II, Fig. 4). This support of the fourth arch by the fifth is similar to that in other clupeids as shown by Ride-wood (1904).

The supporting mechanism is strengthened by the lower pharyngeal bones of the fourth arch. The single bone on each side is moderately strong and gives off both anterior and posterior processes near the mid-line. These processes augment the articular surface with the posterior median ventral cartilage of the branchial basket.

Each half of the organ is shaped roughly like an enlarged fish-hook (or a letter J) lying horizontally in the fish, with the "shank" lateral to the recurved, mesial, anterior terminal portion (Pl. II, Fig. 5), which forms a blind pouch. This sac has a greatly restricted lumen and a very thick wall of both muscular and adipose tissue. In these respects it is structurally unlike the entrance canal (the shank), which leads into it from the dorsal chamber of the pharynx.

Each entrance passage is equipped with two rows of gill rakers. These rakers, like those in the branchial chamber (Pl. II, Fig. 5; Text Fig. 1), are exceedingly numerous and close-set, but they are highly modified in that they are attached along most of one side and lack a denticulate margin. One of these rows is ventral, the other is dorsal; they extend laterally from near the middorsal and midventral lines of the canal respectively and have single free tips, reaching almost to the lateral wall. Here the terminations of the rakers of one series interdigitate with those of the other. Laterad to these interposed tips there is a smaller elongated chamber which is essentially blind at both ends, tapering till it disappears at its anterior and posterior extremities. The dorsal row is continuous through a reduced group of rakers in the dorsal wall of the pharynx with those borne by the fifth ceratobranchial. This row in the canal has a position similar to that which would be carried by a fifth epibranchial, were that bone present. The ventral row lies on the fourth epibranchial bone, for the most part, and is similarly continuous, by reduced rakers, with the typical rakers borne on the posterior (mesial) surface of the ceratobranchial of the fourth arch. The ventral row in the canal is thus obviously the same as the series of rakers normally borne on the posterior margin of the fourth epibranchial in fishes lacking the pharyngeal pouch. This more primitive

arrangement is retained on the third epibranchial in *Dorosoma* (Pl. II, Fig. 6) and on the third and fourth epibranchials of *Clupea*, as shown below in detail. The raker rows terminate anteriorly in the gizzard shad at the sharp angle where the canal connects with the blind pouch (Pl. II, Fig. 5).

The direction and extent of specialization of the pharyngeal structures in the gizzard shad may be shown by comparison with a more generalized clupeid, the Pacific herring (*Clupea pallasii*). For this purpose the following specimens were used: (1) *Clupea pallasii*, 182 mm. in standard length, U. M. M. Z. Cat. No. 61129; (2) *Dorosoma cepedianum*, 188 mm. in standard length.

*Dorosoma* shows a consistent tendency toward increased extension of gill filaments and augmentation of the number of gill rakers. The single row of hyoidean pseudobranch filaments is well developed in both fishes but numbers only nineteen in the Pacific herring, whereas in the gizzard shad there are thirty-one, all rudiments counted. The gills of the first three branchial arches are similar in both species except that in the gizzard shad there is a greater development in the group which arises from the anterodorsal extremity of each of these arches. In the fourth arch the filaments of the lower limb (below the angle between the epibranchial and the ceratobranchial) in both fishes are like those of the same region on the first three arches. On the upper limb of this arch in *Clupea* the double row persists until the most anterior ten filaments are reached. Here the posterior (inner) row (demibranch) ceases, and the ten remaining ones continue the outer row in single file. In *Dorosoma* the posterior row of filaments drops out much sooner after rounding the angle between the upper and the lower limbs. Only twelve pairs are in double series on the upper limb. The remainder continue the outer row to the farthest forward dorsal extremity of this fourth arch and are single. The location of this series of filaments is, however, much different from that in the Pacific herring. In the gizzard shad the row is near the lateral edge of the wing of the epibranchial, but in *Clupea* it is hardly displaced from the normal position along the body of the bone which, in this fish, lacks the winglike expansion.

The distribution of the gill rakers is fundamentally the same in *Clupea* and *Dorosoma*, although their kinds, number, and extent are different. Raker rows are developed in both as follows: on the anterior (lateral, outer) surface of both limbs of all five arches and

also on the posterior (mesial, inner) surface of the upper limb of arch three and the upper and lower limbs of arch four (Table I).

TABLE I

DISTRIBUTION OF GILL-RAKER ROWS IN *DOROSOMA* AND *CLUPEA*

| Branchial arch   | I | II | III | IV | V |
|------------------|---|----|-----|----|---|
| Upper limb ..... | 1 | 1  | 2   | 2  | 1 |
| Lower limb ..... | 1 | 1  | 1   | 2  | 1 |

The typical rakers of *Clupea* are rather uniformly attenuate, tapering only very gradually to a distal point. Each is somewhat laterally compressed and bears two rows of distinct teeth, one on each side. The rakers of *Dorosoma* are more strongly compressed from side to side but possess only very weak denticulations in a single row. Normally each raker is truncate and slightly enlarged distally after a constriction between the tip and the more lamellar base. All the rakers in the herring are similar to the single typical kind described and are stouter than those in the gizzard shad. Those of *Dorosoma*, however, are of two principal kinds. On an ordinary arch segment, such as the upper limb of the first, one out of every three to six rakers has a lappet-like expansion at its base; the intervening rakers lack this expansion.

The great difference in raker numbers between the herring and the gizzard shad is exemplified in the total raker count of the first arch; *Clupea* has sixty-seven, all rudiments included, and *Dorosoma* has more than three hundred (Hubbs and Whitlock, 1929). A similarly larger number is evident on all succeeding arches for the gizzard shad. Augmentation in total number of rakers is also accomplished in this species by great anterior extension of the posterior row of the fourth arch and of the row of the fifth arch. Apparently these two rows have secondarily become encapsulated in the pharyngeal pockets previously described. The corresponding dorsal rows are barely expressed in *Clupea*; the reduced rakers in both the posterior dorsal fourth row and the dorsal fifth row number only five. The total rakers within the pharynx of *Dorosoma* are so numerous and close-set that they obscure all the underlying structures. This is not so in *Clupea*, in which branchial arches and portions of the

pharyngeal floor and roof are not covered by rakers, which thus exposes other structures between them. In a contracted pharynx no spaces are visible to the naked eye between the rakers of *Dorosoma*, and it is only by riffling them that one may discern their individuality. Some increase in raker number is also attained by the continuity of all raker rows of one side with those of the opposite side. In the anterior floor of the pharynx this brings about a much closer encroachment upon the entoglossal in *Dorosoma* than in *Clupea*. In the anterior roof of the pharynx the gizzard shad has a well-developed free median cartilage, which supports the rakers of the first row where they meet on the mid-line and thereby increases their extent. The cartilage is attached posteriorly to the cartilaginous union of the pharyngobranchials of the first branchial arch and is lacking in the Pacific herring.

#### HISTOLOGICAL FEATURES

Description of histological features of the pharyngeal pockets is based on cross sections taken from approximately the middle of their length, cut ten to twelve microns thick, stained with hematoxylin and eosin, and mounted in clarite (Text Fig. 1).

The entrance canal is lined with a stratified squamous epithelium, which is neither glandular nor vascularized. The cartilaginous skeleton of each raker is covered with similar epithelium. Successive layers forming the mesial wall of the entrance canal are: (1) epithelium; (2) submucosa; (3) scattered longitudinal muscle bundles in areolar and adipose connective tissue; (4) thin stratum of circular muscle which is contiguous to a similar musculature surrounding the blind sac. Outside this circular muscle layer, and above and below part of the entrance canal, as well as in all of the wall between it and the sac and over most of the sac, there is more or less compact longitudinal muscle.

The blind sac is also lined with stratified squamous epithelium backed by submucosa of varying thickness. Outside these tissues there is a very thick zone of loose connective tissue, principally adipose. There follow the thin circular muscle layer previously mentioned, the longitudinal bundles, and, finally, the strong circular muscles that extend laterad above and below both sac and canal to insert principally on the cartilaginous capsule. The cartilage is thickened to receive these insertions. A small bundle of longitudinal

muscle is isolated on the ventromesial surface of the organ, lying just over the body of the epibranchial bone.

#### DISCUSSION AND CONCLUSIONS

No definite decision in regard to the function of the pharyngeal pockets in the gizzard shad has been reached. Earlier workers, notably Hyrtl (1855, 1863) and Rauther (1910), have interpreted similar structures in related fishes as of respiratory significance. The pharyngeal pockets of *Dorosoma* do agree in general location, at least, with the accessory respiratory organs of certain tropical fresh-water fishes (Rauther, 1910; Carter and Beadle, 1931), but are probably neither homologous with nor analogous to those organs. These structures in the gizzard shad are very similar to the branchial organs of other clupeoids as described by Hyrtl (1855, 1863), but whether they are of common origin and of similar function remains to be determined. It seems highly probable that Hyrtl erred in attributing a respiratory function to the pharyngeal pockets of clupeoid fishes.

Evidences that the organs in the gizzard shad are accessory to the digestive rather than to the respiratory system are as follows: (1) The epithelial lining of the lumen is stratified and nonvascular;<sup>1</sup> (2) The musculature is striated, indicating a voluntary control; (3) The included lamellar structures are modified rakers with a hard skeleton, not modified gill filaments; (4) The manner in which the organs may be accessory to the digestive system can be postulated on the basis of the structure and location of the organs and on the apparent needs of the fish. The extremely fine, numerous, and close-set condition of the gill rakers doubtless greatly impedes the passage of water. This circumstance may well create a requirement for extra pressure on the water in the pharynx, greater than that needed for expiration in fishes with more ordinary rakers. The extra pressure, partly in the form of an auxiliary head of water, could be provided by the constriction of the pockets and the expulsion of their contents simultaneously with contraction of the pharynx as a whole. With the next inflow of a respiratory current food concentrated on the rakers could then be carried into the expanded

<sup>1</sup> The "flagellated" border on the lining cells reported by Hyrtl (1863) for *Chanos* was not evident in our gizzard-shad material, which, however, was not specially preserved for histological purposes.

dorsal pharyngeal chamber and swallowed. Concentration of the food for swallowing could be due to the nature of the current (possible special turbulence) set up in the chamber or it might be associated with the stricture of the pockets. It seems likely that confusion of water currents, at the level of the esophageal opening, would concentrate foods insufficiently unless such an expanded chamber were present and unless water could pass anteriorly into the pouches. Since the esophagus has an unrestricted opening into the pneumatic duct, it seems unlikely that the pouches serve a function of forcing strained materials into this organ. Any great pressure in the esophagus would push food into the pneumatic duct to the swim bladder.

The possibility of a sensory function, perhaps for the recognition of plankton swarms, is admitted and would account for the conspicuous innervation by the vagus. Hyrtl (1863) concluded that this was the explanation for the richly innervated organ in the osteoglossid *Heterotis niloticus*, where branches of the vagus are distributed to the mucosa.

The obvious anterior sphincter-like constriction of the esophagus at its point of entry into the dorsal pharyngeal chamber must bear some relation to the process of swallowing, but the exact nature of its significance is obscure. Similarly, the reason for the departure of the esophagus from the more usual kind is not clear. In *Dorosoma* its walls are thin and smooth, being quite incapable of much stretching. In *Clupea*, a more generalized clupeid, the anterior part of the esophagus is thick-walled and, although slightly constricted, is beset with numerous villose rugae; posteriorly, too, it is thicker than that in the gizzard shad and is apparently more capable of stretching.

The foregoing comparison seems to indicate that the development of the pharyngeal pockets, with their contained rakers, is, at least indirectly, associated with an increase in the number of gill rakers. This indication supports our contention that the pouches are accessory to the digestive system and not to the respiratory one.

#### SUMMARY

1. Paired pharyngeal pockets constituting an organ associated with the upper limb of the fourth branchial arch and containing two rows of gill rakers are described in the gizzard shad.

2. The organ is lacking in a more generalized clupeid, the Pacific herring.

3. Evolution appears to be the result of an increased number of gill rakers.

4. Function is not respiratory but is accessory to that of the digestive tract.

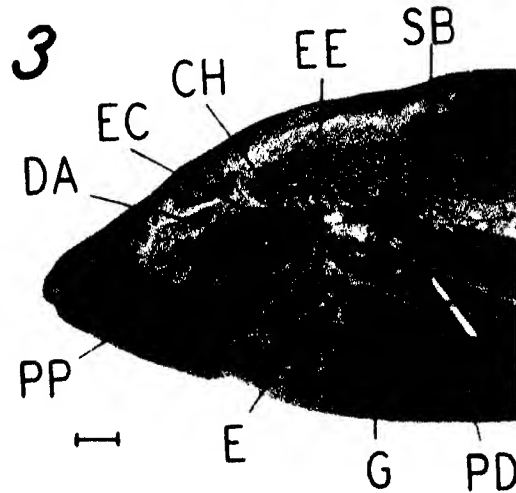
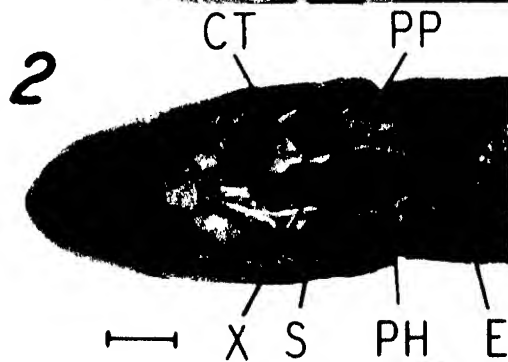
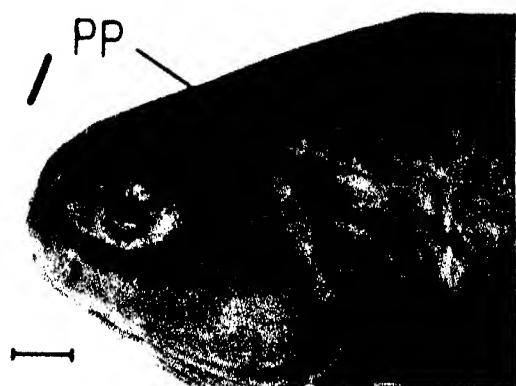
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### EXPLANATION OF PLATE I

(The scale bar equivalent is one centimeter.)

- FIG. 1. Gizzard shad with opercle and preopercle removed to show lateral surface of pharyngeal pocket (PP) *in situ*. Adult female, 261 mm. in standard length, Grassy Pond, Gibson County, Indiana, summer, 1940.
- FIG. 2. Pharyngeal pockets (PP) of gizzard shad exposed from above. CT, cartilaginous extension of fourth epibranchial bone; E, esophagus; PH, roof of pharynx; S, space between pharyngeal organs; X, innervation by vagus nerve. Adult male, 224 mm. in standard length, Grassy Pond, Gibson County, Indiana, summer, 1940.
- FIG. 3. Parasagittal section of anterior portion of gizzard shad. CH, chamber resulting from dorsal expansion of pharynx; DA, dorsal aorta; E, esophagus with thin wall; EC, opening of entrance canal of right pharyngeal pocket into chamber; EE, point of exit of esophagus from pharyngeal chamber; G, gizzard; PD, pneumatic duct from esophagus to swim bladder; PP, mesial surface of right pharyngeal pocket; SB, swim bladder. Adult female, 240 mm. in standard length, Grassy Pond, Gibson County, Indiana, summer, 1940.





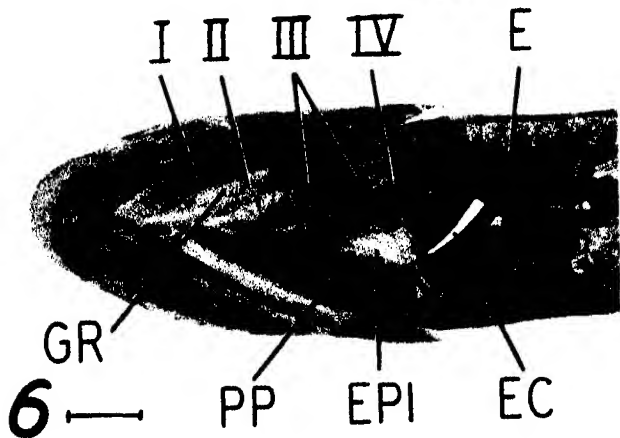
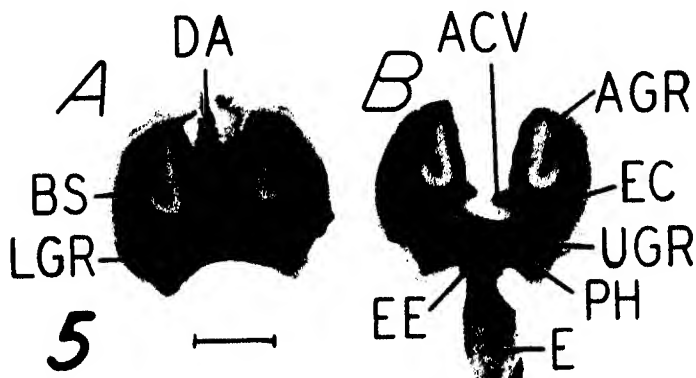
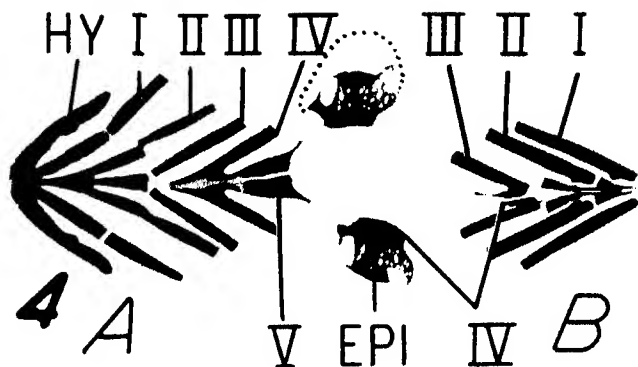
## EXPLANATION OF PLATE II

(The scale bar equivalent is one centimeter.)

FIG. 4. Alizarin preparation of branchial bones of gizzard shad for reference to the modification of the fourth epibranchials for support of the pharyngeal pockets. There are shown a dorsal view of the lower bones (A) and a ventral view of the upper bones (B), 1.25 times actual size. HY, Hyoid arch; I, first branchial arch; II, second branchial arch; III, third branchial arch; IV, fourth branchial arch; V, fifth branchial arch (ceratobranchial); EPI, epibranchial bone of fourth gill arch — extent of reflected cartilaginous expansion indicated by dashed line. Male specimen, 172 mm. in standard length, taken in Lake Erie, vicinity of Put-in-Bay, Ohio, October, 1943

FIG. 5. Frontal sections of pharyngeal pockets and dorsal chamber of pharynx, showing structure of pockets and relation to opening of esophagus. A, ventral section viewed from above; B, dorsal section viewed from below; ACV, anterior cardinal vein (?); AGR, anterior limit of gill raker rows in entrance canal; BS, blind sac; DA, dorsal aorta; E, esophagus with thin wall; EC, opening of entrance canal of right pharyngeal pocket into chamber; EE, entrance to esophagus; LGR, lower row of rakers; PH, roof of pharynx; UGR, upper row of rakers

FIG. 6. Roof of pharynx exposed and dissected by removal of arches two and three on right side of fish. I IV, upper limbs of gill arches one through four; E, esophagus; EC, pointer into entrance canal of right pharyngeal pocket; EPI, epibranchial of fourth gill arch with pharyngeal pocket on its dorsal surface; GR, gill rakers; PP, ventrolateral surface of right pharyngeal pocket covered by expansion of fourth epibranchial





# FISH POPULATIONS IN AND AROUND BRUSH SHELTERS OF DIFFERENT SIZES PLACED AT VARYING DEPTHS AND DISTANCES APART IN DOUGLAS LAKE, MICHIGAN \*

IMMANUEL A. RODEHEFFER

**I**N FORMER numbers of the *Michigan Academy Papers* the writer has presented various data on the use of brush shelters by fish and on the movements of marked fish in Douglas Lake, Cheboygan County, Michigan (Rodeheffer, 1939, 1940, 1941). As these studies progressed and public interest in lake improvement increased it became apparent that answers were needed to numerous problems which had already been suggested in "The Improvement of Lakes for Fishing" (Hubbs and Eschmeyer, 1938). Scientists, fisheries managers, and fishermen wanted practical answers to many urgent questions.

At what depth should artificial fish shelters be placed in a lake to be most suitable for certain species favored by anglers? Do the young, the half-grown ones, and adults of such species have individual depth preferences? Among the many factors which may govern the optimum depth for shelters consideration may be given to the species of fish for which protection or utilization is desired, the seasonal movements of the fishes, temperature (particularly during the summer months), extent of light penetration, relative amounts of deep and shallow water in a lake, ice and wave action, fluctuations in water level, and types of bottom at various depths.

Another question that puzzles the individual who attempts to improve a lake by installing shelter devices is, How many shelters should be put in a given area, or how far apart should such constructions be placed for maximum efficiency? It is self-evident that numerous factors must be considered when answering this question, such as the available food supply, the habits of the species for which

\* Contribution from the Institute for Fisheries Research of the Michigan Department of Conservation and the Biological Station of the University of Michigan.

protection is desired, the amount of bottom area suitable for shelters, the funds available for the work, and the abundance of natural cover.

Shall a few large shelters or numerous small ones be installed in a lake? This is a question often asked after several shelters have been built and placed. Much brush and much labor are required to build large shelters. They are difficult to handle and place where wanted. Economy in the building and placement of large and small shelters is dependent upon the materials and the equipment immediately available. The suggestion has been made that small shelters be built for young fish and large shelters for "keeper" fish (Hubbs and Eschmeyer, 1938:66). Limited testing has supported the value of the proposal.

During the summer months of 1941 and 1942 studies designed to answer these questions were undertaken on Douglas Lake at the University of Michigan Biological Station.

#### ACKNOWLEDGMENTS

Again the writer acknowledges with gratitude the coöperation of Dr. A. S. Hazzard, director of the Institute for Fisheries Research, in planning this work and interpreting the data. Dr. A. H. Stockard, director of the Biological Station of the University of Michigan, offered advice and equipment. As in former studies, the guidance in this investigation and the help given in the preparation of this report by Dr. Carl L. Hubbs have been invaluable. The funds necessary to carry on this work were provided by the Institute for Fisheries Research of the Michigan Department of Conservation. The Fish Division of the Michigan Department of Conservation, through Mr. O. H. Clark, furnished the labor required. Professor W. F. Ramsdell, of the University of Michigan School of Forestry and Conservation, supplied means of cutting and transporting the brush used in the construction of shelters. To these individuals and others who made this undertaking possible the writer offers his sincere thanks.

#### FISH POPULATIONS IN AND AROUND BRUSH SHELTERS PLACED AT DIFFERENT DEPTHS

To obtain evidence on the optimum depth for the placement of brush shelters six shelters of the hollow-center type (Hubbs and Eschmeyer, 1938:80-81, fig. 20) were installed on the shoals of North

Fish-Tail Bay, in Douglas Lake, two each at depths of five, ten, and fifteen feet. This region was selected for two main reasons: (1) The terrigenous bottom slopes evenly to a depth of twenty feet or more, with only moderate differences in angles of slope; (2) The bottom is of sand, covered by a thin layer of flaky marl. The area thus provided a uniform habitat without vegetation or bottom irregularities, which might have concentrated the fish locally. The shelters, similarly constructed and spaced at equal intervals, could therefore be assumed to present approximately equal availability and attraction, except for the one factor being tested, that of depth of water. Furthermore, the bottom was favorable for seining, so that the total fish population in and about each structure could be caught periodically for counting.

The experiment was run in duplicate. The six shelters were placed in pairs 200 feet apart, with one pair on the 5-foot contour, one pair on the 10-foot contour, and the other two at 15 feet. The outermost structures were about 400 and 500 feet from shore. The pairs were staggered in such a fashion that no shelter was nearer than 200 feet to any other.

#### STRUCTURES AND EQUIPMENT

The shelters were made as nearly identical as possible. Scrub-oak and maple poles were used for the frames, which consisted of an inner unit 9 feet square, with the ends of the poles protruding beyond the square, and a surrounding frame  $11\frac{1}{2}$  feet square. The larger unit was fastened to the protruding ends of the smaller one in such a way as to make a sturdy base for the brush. The brush, consisting of maple, scrub oak, tag alder, and cherry, was placed in bundles about 18 inches in diameter at the butt end and laid on this frame, with the tops pointing away from the center. Each bundle was securely wired to the pole of the inner frame with number 9 galvanized wire. All bundles were placed as close together as possible, so as to form a complete circle. The outer edges were trimmed, making each shelter 18 feet in diameter. The double framework provided a flat surface on the bottom which permitted the net to slide under the shelter when it was raised to the surface. To facilitate raising, a special bridle was attached to the four corners of the inner frame, with a sufficient length of wire to allow the apex of the bridle to be fastened to a float.

A specially constructed fine-meshed bag seine was used for capturing the fish populations around these shelters. This seine, 158 feet in length, was made with a center section, of  $\frac{1}{4}$ -inch square mesh, which formed a bag 8 feet long, 8 feet wide, and 12 feet deep, tapering to 4 by 4 feet at the closed end. On each side of the bag for 47 feet the seine was 12 feet deep and made of  $\frac{3}{8}$ -inch mesh. The end sections, 28 feet in length and tapering to 6 feet in depth, were of  $\frac{3}{4}$ -inch mesh. The seine was equipped with sufficient floats to keep it upright in the water and with enough weights to hold the lead line on the bottom. The net was laid from a boat outside a shelter in such a fashion that the device was completely encircled. Ropes fastened to the brails led to shallow water, and thus allowed the net to be pulled shoreward under the shelter immediately after the structure was hoisted to the surface. While being hauled toward shore the seine was pursed by keeping the brails together, so as to prevent the escape of the fish already in the net and the capture of any fish in the water between the shelters and the beach. For seining the fish from the shelters in 15 feet of water a straight seine 5 by 100 feet made of  $\frac{3}{8}$ -inch mesh was fastened to the top of the center section of the bag seine.

In earlier experiments with brush shelters (Rodeheffer, 1939, 1940, 1941) the structures were pulled to shallow water after being enclosed by the net. When the fish had been gathered the shelter was replaced in its original position. To save time, labor, and wear on the shelters Dr. A. S. Hazzard suggested that a floating hoist be used for lifting the shelters to the surface, so that the seine could be pulled under them. The hoist that was constructed (Fig. 1) had a base 25 by 25 feet. Nine oil drums, later increased to thirteen, were fastened at the corners of this hoist to give it buoyancy. Poles extending upward from the corners of the square were brought together to form an apex twenty feet above the surface of the water. The framework was equipped with a steel cable extending from a geared drum and a hand-operated crank secured at one of the corners, passing upward through a fixed pulley at the peak and downward to the surface of the water. At this point the cable was threaded through a movable pulley, brought upward, and fastened to the fixed pulley at the top. The pulley was hooked onto the bridle attached to the shelter, after the floating hoist had been anchored over the shelter. The turning of the crank wound the

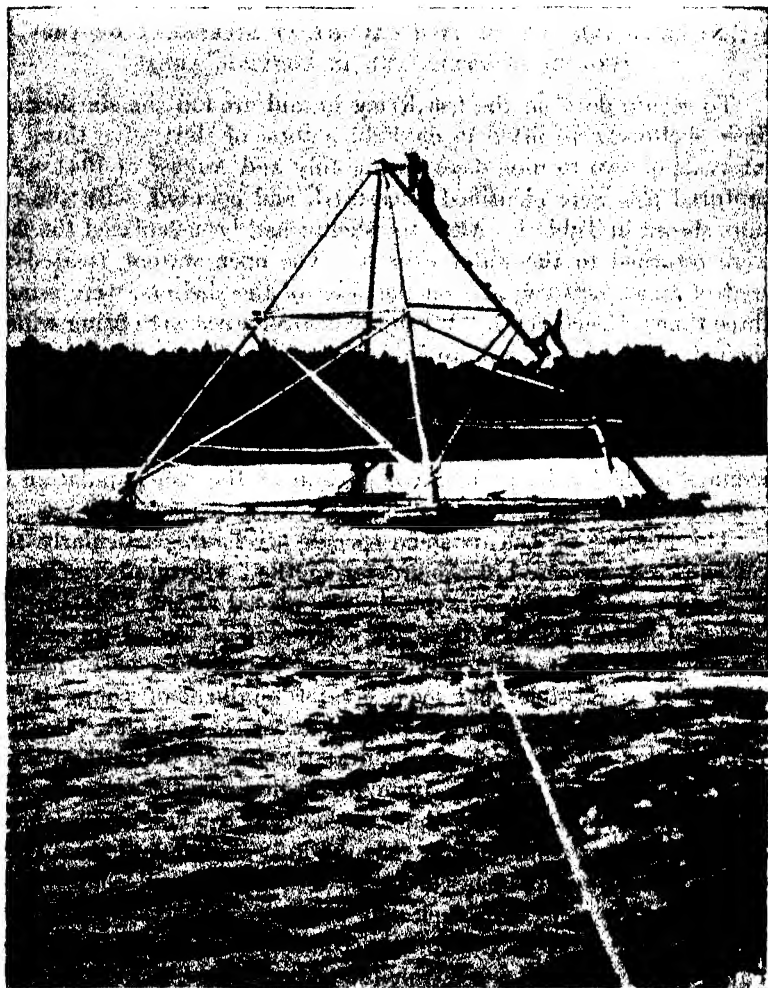


FIG. 1. Hoist used in lifting brush shelters. The device is being towed to the site of a shelter

cable on the drum, and thus lifted the installation to the surface (the power ratio of the block and tackle and gears was 1 : 34). After the seine had been hauled through the area, the shelter was lowered to its original position.



NUMBER AND SIZE OF FISH CAUGHT AT DIFFERENT DEPTHS  
AROUND SHELTERS AND IN CONTROL AREAS

To secure data on the fish living in and around the six shelters these shelters were lifted in daylight a total of thirty-five times at intervals of two to nine days during July and August of 1941. All captured fish were identified, measured, and counted, with the results shown in Table I. After the shelter had been replaced the fish were returned to the water over it. The open waters, treated as control areas, between and on the sides of the shelters, were seined three times at each depth. When the control areas were being seined the net was laid in a circle to cover an area similar to that encircled when taking fish in and around a shelter. While the net was brought shoreward the brails were kept together to prevent the capture of fish from waters other than the designated control areas. These seinings formed a basis for a comparison of the fish population in and around shelters and in similar places without protection.

The number of fish of some species per haul, particularly the yellow perch, increased at the greater depths. The number of perch per haul was less than 3 in the shelters placed at the 5-foot depth, increased to 142 per haul from the shelters in 10 feet of water, and mounted to almost 1,000 per haul from the shelters in 15 feet of water. It is possible that even greater numbers of young perch would be protected by shelters placed deeper than 15 feet. Control areas yielded only 4 perch per haul at the 10-foot depth, and none at 5 or 15 feet. The perch from the shelters at the three depths varied little in size. The modal-size class was 5-6 cm. at all depths. There is another common size (age group?) at about 11 cm. Only 6 perch of legal size (6 inches or more) were recorded, all from shelters in 15 feet of water. The fact that perch are markedly dwarfed in Douglas Lake (Weller, 1938) may account for the limited size range. Large schools of small fish (estimated to be 2-3 cm. long), so densely crowded as to give the water a bluish-green tinge, sometimes rose to the surface when a shelter was being lifted from 15 feet of water and, occasionally, from a shelter at the 10-foot depth. Capture of a few of these with a hand net revealed them to be young yellow perch. The shelters harbored thousands of these fish, but they were too small to be retained by the net and hence are not included in the table.

TABLE I

NUMBER PER HAUL AND SIZE (TOTAL LENGTH IN CENTIMETERS) OF FISH OF EACH SPECIES TAKEN FROM  
HOLLOW-CENTER BRUSH SHELTERS PLACED AT DIFFERENT DEPTHS IN DOUGLAS LAKE, MICHIGAN

| Species *           | Number per haul at given depths |                       |                       | Size range at given depths |           |           | Average size at given depths |         |         |
|---------------------|---------------------------------|-----------------------|-----------------------|----------------------------|-----------|-----------|------------------------------|---------|---------|
|                     | 5 feet<br>(10 hauls)            | 10 feet<br>(13 hauls) | 15 feet<br>(12 hauls) | 5 feet                     | 10 feet   | 15 feet   | 5 feet                       | 10 feet | 15 feet |
| Game fishes         |                                 |                       |                       |                            |           |           |                              |         |         |
| Northern pike       | 2.7                             | 142.2                 | 996.5                 | 5.0-13.4                   | 3.1-14.7  | 63.0-63.0 | 7.7                          | 5.5     | 63.0    |
| Yellow perch        | 7.0                             | 6.2                   | 1.3                   | 4.3-22.2                   | 4.2-18.7  | 3.5-21.7  | 7.7                          | 7.9     | 5.4 †   |
| Smallmouth bass     | 29.1                            | 15.7                  | 3.3                   | 3.5-7.2                    | 3.1-8.2   | 3.5-10.5  | 5.3                          | 4.9     | 10.7    |
| Largemouth bass     | 0.3                             | 0.2                   | ...                   | 10.0-15.3                  | 9.8-14.6  | ...       | 12.2                         | 12.2    | 5.9     |
| Bluegill            | 55.2                            | 60.0                  | 56.3                  | 1.9-17.1                   | 1.5-19.0  | 1.9-19.7  | 8.3                          | 8.3     | 9.0     |
| Pumpkinseed         | 67.0                            | 64.8                  | 44.7                  | 2.1-21.6                   | 2.5-19.7  | 2.3-28.5  | 8.9                          | 8.2     | 11.5    |
| Rock bass           |                                 |                       |                       |                            |           |           |                              |         |         |
| Coarse fishes       |                                 |                       |                       |                            |           |           |                              |         |         |
| Sucker              | 0.2                             | 0.2                   | 0.5                   | 37.9-40.6                  | 37.8-41.8 | 5.9-39.8  | 39.0                         | 38.8    | 22.5    |
| Bullhead            | 0.3                             | 0.5                   | 0.8                   | 6.2-7.4                    | 4.7-7.1   | 4.4-7.0   | 6.8                          | 5.8     | 5.9     |
| Forage fishes       |                                 |                       |                       |                            |           |           |                              |         |         |
| Common shiner       | 0.3                             | ...                   | 0.7                   | 5.3-6.0                    | ...       | 5.2-11.0  | 5.8                          | ...     | 8.3     |
| Spottail shiner     | 3.5                             | 7.2                   | 90.8                  | 2.7-6.7                    | 1.9-9.3   | 1.5-9.3   | 5.1                          | 4.8     | 5.0 †   |
| Sand shiner         | 1.2                             | 0.2                   | 3.2                   | 2.1-7.2                    | 1.6-6.0   | 4.4-7.6   | 4.3                          | 4.5     | 6.3     |
| Mimic shiner        | ...                             | ...                   | 0.6                   | ...                        | ...       | 2.2-6.0   | ...                          | ...     | 3.6     |
| Log perch           | 0.7                             | 21.5                  | 37.3                  | 4.7-10.6                   | 5.3-10.6  | 4.3-12.5  | 9.1                          | 8.9     | 8.9     |
| Johnny darter       | 2.5                             | 5.7                   | 5.0                   | 3.1-5.8                    | 2.1-6.1   | 3.3-7.1   | 4.6                          | 4.4     | 4.7     |
| Iowa darter         | 0.2                             | 0.8                   | 0.4                   | 3.4-4.4                    | 2.9-5.7   | 3.6-5.5   | 4.0                          | 4.8     | 4.8     |
| Mudler              | ...                             | 0.1                   | 0.1                   | ...                        | 2.8-2.8   | 7.0-7.0   | ...                          | 2.8     | 7.0     |
| Total fish per haul | 170.2                           | 325.3                 | 1,241.6               | ...                        | ...       | ...       | ...                          | ...     | ...     |
| Total fish taken    | 1,702                           | 4,226                 | 14,899                | ...                        | ...       | ...       | ...                          | ...     | ...     |

\* The scientific names are listed at the end of the article.

† Only a percentage of the perch between 3 and 7 centimeters and of the spottail shiner between 4 and 8 centimeters were measured; the others were merely counted. The average sizes for these species are based on actual measurements taken.

Certain other species, such as the largemouth and the smallmouth bass, showed a definite preference for the shelters in shallower water. Shelters in 5 feet of water harbored almost twice as many largemouth bass as those in 10 feet of water and about nine times as many as those placed at 15-foot depths. The shallowest shelters produced more than five times as many smallmouth bass as the deepest ones and slightly more than the shelters in 10 feet of water. Young smallmouth bass, although present in small numbers, appeared consistently in every haul from the shelters in 5 feet of water. This substantiates former findings (Hubbs and Eschmeyer, 1938: 64). Largemouth bass were taken in greater numbers than the smallmouth bass, but this is possibly due to the type of bottom, which is a flaky marl. The young of these species, having a size range of 3 to 10 cm., were the most common, with a scattering of smallmouth bass 14 to 25 cm. long from the shelters at all three depths. No fish of legal size (10 inches or more) were caught. Nine seinings of the control areas netted a total of only 6 young smallmouth bass at the 5-foot depth and 2 in 10 feet of water. Only one largemouth bass was taken in the 10-foot controls, and none was captured at the 5-foot depth. No largemouth or smallmouth bass were taken from the controls in 15 feet of water.

The pumpkinseed, ranking second in abundance in shelters on the 5- and 15-foot contours and third in shelters in 10 feet of water, was found in about equal numbers at all depths. Nor was there any marked difference in the minimum, maximum, average, or modal size of the fish taken from the shelters at the stated depths. Two sizes are commonly represented, one of about 3 to 4 cm. and the other of about 7 to 8 cm. Only a few (18) were of legal size (6 inches or more). That this fish seeks protection is apparent when one considers that no pumpkinseeds were taken from the shallow controls, only 2 from the control areas in 10 feet of water, and just 1 from the controls at the 15-foot depth.

The number of rock bass taken from the shelters showed a slight but gradual decline with increasing depth of water. Hauls from the shelters on the 5-foot contour averaged about 1.5 times as many rock bass as those on the 15-foot contour. Rock bass 7 to 8 cm. long were particularly common around shelters at all three depths, and constituted almost one third of all the rock bass taken. However, enough larger rock bass were taken from the deep shelters to increase

the average size from 8 to 9 cm. for the shelters in 5 and 10 feet of water and to 11.5 cm. from the shelters at the 15-foot depth. This increase was primarily due to the number of fish taken in the size range between 8 and 15 cm. Only 32 of the 316 fish 8 cm. or more in length were of legal size (6 inches or more). The percentages of legal-sized fish among the rock bass caught from the shelters on the 5-, 10-, and 15-foot contours were 3.7, 1.2, and 6.0, respectively. Although fewer rock bass inhabited the shelters in the deepest water, those found there included the highest percentage of legal size. No rock bass were taken in the seining in the control areas.

The almost total absence of northern pike in the shelters was surprising, for Douglas Lake is known as a good pike lake. These fish are commonly caught in the larger weed beds, which in places extend from shallow water to a depth of about 18 feet. The capture of only one northern pike from a shelter in 15 feet of water indicates that this fish does not seek such a habitat.

Very few bluegills were taken about the shelters, but this does not indicate a lack of preference for brush cover on the part of this species. Bluegills are not common in Douglas Lake. Artificial plantings have been made, but these fish do not seem to reproduce naturally to any extent. Seining of waters where one might expect to take bluegills seldom yielded any results.

Several of the forage fishes were well represented in the catches from the shelters. The spottail shiner sought protection in the deeper shelters. Ninety-one fish per haul were taken from the deepest water, whereas only 7 fish per haul were seined from the 10-foot contour shelters and fewer than 4 per haul were caught in shelters on the 5-foot contour. Only one spottail was taken from the control areas, and it was at the 10-foot depth. Only a little variation in size was noted from all three depths. Most of the fish were young and half grown.

The largest numbers of log perch were found in the deeper water adjoining the shelters. The average catch was less than one fish per haul from the shelters in 5 feet of water. This increased to over 21 fish per haul from shelters on the 10-foot contour and to more than 37 fish per haul from the shelters in 15 feet of water. Seining of the control areas at the 10-foot depth netted almost 6 fish per haul. No fish were taken at the two other depths. The average size was about 9 cm. at all depths.

The Johnny darter, well known as a fish of the open bottom, was captured in comparatively small numbers in the shelters — about 5 fish per haul from shelters on the 10- and 15-foot contours, and 2.5 per haul from the shelters at the 5-foot depth. In the control areas this species averaged more fish per haul than any other. Seining of the controls at the 10- and 15-foot depths captured 5 fish per haul and from the 5-foot control areas the hauls netted an average of 15 fish.

Almost all suckers caught were adults. In the control areas the 3 suckers captured at 15 feet and the 6 taken at 10 feet were full grown. The one fish taken at 5 feet was young, being 7 cm. long.

Other species seined in the shelters listed in Table I were recorded in such small numbers in both the control areas and the shelters that conclusions are not warranted.

The total catch of fish per seine haul from the shelters increased with an increase in depth. Brush shelters placed on the 5-, 10-, and 15-foot contours averaged 170, 325, and 1,241 fish per haul, respectively. It should be noted, however, that these figures are largely influenced by the perch catch.

Control areas at the same depths averaged 13, 16, and 8 fish per haul. These numbers emphasize the fact that fishes in general seek shelter.

#### FISH TAKEN FROM SHELTERS PLACED 50 AND 200 FEET APART

The determination of the most desirable concentration of shelters in a lake was one of the major projects for the summer of 1942. To provide information on this subject fish collections were made from brush shelters placed 50 and 200 feet apart. For this experiment eight hollow-center shelters were used. Four of these were placed on the 8-foot contour, 50 feet apart. The other four were located at the same depth but at a distance of 200 feet from one another. To reduce the cost and to save labor the six constructions made in 1941 to test the effectiveness of such devices at different depths were used. Two additional shelters were built in 1942 in replica of the six already made. All these were placed in North Fish-Tail Bay in the same locality where they had been used the summer before. Fish populations were determined as in the previous experiment, by means of the hoist and the large seine. The determinations were made only for the two center shelters in each

group. To reduce the variables the two newly built shelters were placed at the ends. Fish of all species taken from the installations and from the control areas between the shelters were identified, counted, and measured (Table II). A study of the data reveals little variation in the average size of the fish netted from either group of protection devices.

The capture of northern pike in shelters 50 feet apart arouses interest. The data presented are too scanty to warrant definite conclusions, but they suggest that this species may utilize close-set shelters.

Yellow perch averaged about 114 fish per haul from the brush constructions separated by 200 feet, and 51 per haul from those set 50 feet apart. None of the 1,022 fish taken in the shelters that were 200 feet apart were of legal size, and only 5 of the 559 fish caught in the more closely placed covers were 6 inches or more in length (it should be noted again that the perch of Douglas Lake are greatly stunted). Control areas of 200 and 50 feet between shelters yielded an average of 2.2 and 3.8 fish per haul, respectively.

Rock bass also concentrated more heavily in brush constructions separated by the greater distance. Shelters 200 feet apart produced 367, or an average of 41 per haul. Eight of these were 6 inches or more in length. Only 234, or 21 per haul, were netted from shelters 50 feet apart. Nine of these were legal-sized fish. No rock bass were taken in hauls from the control areas.

Smallmouth bass, brown bullheads, and log perch, although taken in small numbers, showed a similar tendency to collect in larger numbers in shelters separated by the greater distance. Smallmouth bass averaged 2.1 and 0.4 fish per haul from shelters separated by 200 and 50 feet. Only 3 fish from the more widely separated shelters were of legal size. Control hauls caught 0.3 fish per haul between the devices placed close together and 0.2 per haul between those farther apart. The brown bullhead averaged 2.4 fish per haul from shelters set 200 feet apart and 0.9 per haul from those separated by a distance of 50 feet. None were taken in the control areas. The log perch produced 3.6 and 1.6 fish per haul from the shelters separated by distances of 200 and 50 feet, respectively. The larger control yielded 4 fish per haul; the smaller one, 3.

The largemouth bass were netted in approximately equal numbers (about 6 per haul) from each group of shelters. Almost all the

TABLE II  
 NUMBER PER HAUL AND SIZE (TOTAL LENGTH IN CENTIMETERS) OF FISH TAKEN FROM HOLLOW-CENTER  
 BRUSH SHELTERS PLACED DIFFERENT DISTANCES APART IN DOUGLAS LAKE, MICHIGAN

| Species             | Number per haul at<br>given distances |                       | Size range at<br>given distances |            | Average size at<br>given distances |         |
|---------------------|---------------------------------------|-----------------------|----------------------------------|------------|------------------------------------|---------|
|                     | 200 feet<br>(9 hauls)                 | 50 feet<br>(11 hauls) | 200 feet                         | 50 feet    | 200 feet                           | 50 feet |
| Game fishes         |                                       |                       |                                  |            |                                    |         |
| Northern pike       | 0.2                                   | 1.4                   | 26.8-47.5                        | 17.3-192.0 | 37.0                               | 35.6    |
| Yellow perch        | 113.6                                 | 50.8                  | 4.8-14.5                         | 5.5-20.3   | 9.8                                | 9.9     |
| Smallmouth bass     | 2.1                                   | 0.4                   | 2.8-40.5                         | 13.5-16.0  | 16.2                               | 14.8    |
| Largemouth bass     | 5.8                                   | 5.9                   | 3.3-35.0                         | 3.2-35.3   | 5.9                                | 5.8     |
| Bluegill            | 0.3                                   | 0.6                   | 7.0-7.7                          | 7.2-8.6    | 7.5                                | 8.4     |
| Pumpkinseed         | 69.7                                  | 75.6                  | 2.3-18.6                         | 2.2-17.3   | 6.4                                | 5.3     |
| Rock bass           | 40.8                                  | 21.3                  | 2.1-19.8                         | 2.7-18.5   | 9.4                                | 9.2     |
| Coarse fishes       |                                       |                       |                                  |            |                                    |         |
| Sucker              | 0.8                                   | 0.2                   | 33.0-42.7                        | 37.3-39.0  | 38.8                               | 38.5    |
| Bullhead            | 2.4                                   | 0.9                   | 10.2-15.5                        | 6.5-15.7   | 13.3                               | 12.1    |
| Forage fishes       |                                       |                       |                                  |            |                                    |         |
| Spotail shiner      | 0.4                                   | 1.4                   | 4.2-4.5                          | 2.1-4.8    | 4.5                                | 4.0     |
| Sand shiner         | ...                                   | 0.4                   | ...                              | 2.8-3.7    | ...                                | 3.5     |
| Log perch           | 3.6                                   | 1.6                   | 6.7-10.7                         | 8.5-10.4   | 9.6                                | 9.5     |
| Johnny darter       | 0.9                                   | 2.4                   | 3.7-5.5                          | 3.3-5.8    | 4.6                                | 4.4     |
| Iowa darter         | 0.3                                   | 0.5                   | 4.0-5.5                          | 4.2-5.6    | 4.8                                | 5.2     |
| Mudler              | ...                                   | 0.1                   | ...                              | 3.0-3.0    | ...                                | 3.0     |
| Total fish per haul | 240.9                                 | 163.5                 | ...                              | ...        | ...                                | ...     |
| Total fish taken    | 2,168                                 | 1,797                 | ...                              | ...        | ...                                | ...     |

fish were young, only one legal-sized fish being taken from shelters in each group. Control areas between the devices separated by a distance of 50 feet averaged 2 young largemouth bass per haul. None were caught in the others. Adams and Hankinson (1928: 481) observed that the largemouth bass showed a decided preference for areas with an abundance of vegetation and also that the young over an inch in length were solitary. Placing shelters close together may make not only the shelters but the areas between them a good habitat for the young of this species.

The pumpkinseed congregated in slightly larger numbers in shelters set close together. The average haul netted about 76 pumpkinseed from installations placed 50 feet apart and 70 fish from those located 200 feet apart. Open waters between the artificial covers installed 50 feet apart yielded 7.5 fish per haul, or more than twice the number (3.6 per haul) taken between shelters sunk 200 feet apart. Almost all fish taken in the shelters and the controls were young, with a modal size of 3 to 4 cm. Probably other age groups at 6 to 7 cm. and 9 to 10 cm. are represented in the pumpkinseed populations. Only one legal-sized fish was netted from the shelters placed close together. Nine legal-sized fish were taken from the other shelters.

The spottail shiner and the Johnny darter, although poorly represented in the hauls, averaged more in shelters placed close together. The few suckers taken in the shelters and the one taken in the wider open water were all adults. Other species, namely, the bluegill, the sand shiner, the Iowa darter, and the northern muddler, were caught in such limited numbers in both the shelters and controls that interpretations are not attempted.

Shelters placed 200 feet apart yielded 240 fish of all species per seine haul. Those 50 feet apart averaged 163 fish per haul. The shelters spaced four times as far apart yielded 1.5 times as many fish per shelter. More fish per unit length of shoreline were therefore sheltered when the constructions were placed closer together, though fewer fish were then concentrated about each installation. The open water between shelters, designated as control areas, harbored more fish when shelters were placed close together. These control areas, which were seined nine times, produced 18 fish per haul between the shelters 50 feet apart and 13 fish per haul between those placed at the greater distance.



FISH TAKEN IN AND AROUND BRUSH SHELTERS  
OF DIFFERENT SIZES

In order to determine the relative effectiveness of shelters of different sizes six structures of the ladder-shaped type (Hubbs and Eschmeyer, 1938:74-79) were built and installed in 1942. Three of these were trimmed to  $16 \times 12 \times 3$  feet, and three were made  $8 \times 6 \times 3$  feet. The smaller ones, therefore, had one half the area and one fourth the volume of the larger. Except for size all were as nearly identical as possible. The available brush (cherry, ironwood, beech, oak, and maple) was closely packed, and the shelters were installed on the 8-foot contour along the south shore of Bryants Bay. Here the clean and fairly hard packed bottom is largely composed of sand, clay, and some rocks ranging in size from that of a baseball to that of a man's head. The area is devoid of aquatic vegetation. Conditions along the line of installation were rather uniform. The shelters, alternately large and small, were spaced 200 feet apart.

Again the hoist and net employed in former operations were used to catch populations in and around the shelters. Fourteen hauls were made from the larger shelters and 17 from the smaller ones. The fish from all six shelters were identified, counted, and measured (Table III). Areas between shelters were seined five times to furnish a comparison of fish populations in and around shelters as contrasted with those in the open areas in this part of Douglas Lake.

Rock bass were taken in the ratio of 5 to 12 from the small and the large shelters. More legal-sized fish were netted from the bigger constructions, where 44 fish 6 inches or more in length were captured. Twenty-nine legal fish were caught from the other shelters. However, the greater percentage of these fish came from the smaller shelters, which harbored 8.4 per cent, whereas the larger ones yielded only 6.5 per cent.

Pumpkinseed were also found in greater numbers in the larger shelters. Here they averaged 29 per haul. In the smaller shelters the average haul netted about 19 fish. Two dominant size classes are represented, 5-6 and 9-10 cm. in total length; the smaller ones were somewhat more abundant in the smaller shelters; the larger ones were more common in the larger shelters. Only 4, or about 1.0

TABLE III

NUMBER PER HAUL AND SIZE (TOTAL LENGTH IN CENTIMETERS) OF FISH TAKEN FROM LARGE AND SMALL LADDER-SHAPED BRUSH SHELTERS IN DOUGLAS LAKE, MICHIGAN

| Species             | Number per haul from different shelters |                      | Size range from different shelters |           | Average size from different shelters |        |
|---------------------|-----------------------------------------|----------------------|------------------------------------|-----------|--------------------------------------|--------|
|                     | 16 feet<br>(14 hauls)                   | 8 feet<br>(17 hauls) | 16 feet                            | 8 feet    | 16 feet                              | 8 feet |
| Game fishes         |                                         |                      |                                    |           |                                      |        |
| Northern pike       | 0.1                                     | ...                  | 16.2-16.7                          | ...       | 16.5                                 | ...    |
| Yellow perch        | 24.4                                    | 27.2                 | 7.5-16.0                           | 6.0-15.5  | 10.6                                 | 9.8    |
| Smallmouth bass     | 1.9                                     | 1.2                  | 5.1-38.2                           | 5.2-39.0  | 23.0                                 | 16.9   |
| Largemouth bass     | 1.2                                     | 1.3                  | 3.4-6.1                            | 3.5-5.7   | 4.4                                  | 4.5    |
| Bluegill            | 0.4                                     | ...                  | 7.2-8.3                            | ...       | 7.8                                  | ...    |
| Pumpkinseed         | 28.9                                    | 18.6                 | 2.6-20.6                           | 2.0-20.1  | 8.5                                  | 8.5    |
| Rock bass           | 48.1                                    | 20.3                 | 2.4-26.6                           | 2.7-27.8  | 11.1                                 | 11.1   |
| Coarse fishes       |                                         |                      |                                    |           |                                      |        |
| Sucker              | 1.5                                     | 0.6                  | 35.9-41.0                          | 34.6-40.7 | 38.8                                 | 38.8   |
| Bullhead            | 0.2                                     | 0.1                  | 3.3-5.9                            | 3.2-3.2   | 4.5                                  | 3.2    |
| Forage fishes       |                                         |                      |                                    |           |                                      |        |
| Common shiner       | ...                                     | 0.1                  | ...                                | 4.7-4.7   | ...                                  | 4.7    |
| Spottail shiner     | 5.2                                     | 14.8                 | 2.0-5.0                            | 2.0-4.0   | 3.0                                  | 3.0*   |
| Sand shiner         | 1.0                                     | 3.8                  | 5.0-7.0                            | 5.2-8.3   | 6.0                                  | 6.4    |
| Log perch           | 2.3                                     | 1.6                  | 5.5-10.5                           | 9.2-10.0  | 9.5                                  | 9.9    |
| Johnny darter       | 0.3                                     | 0.2                  | 3.3-4.5                            | 2.5-4.5   | 3.8                                  | 3.5    |
| Mudpiper            | 0.1                                     | ...                  | 2.7-7.0                            | ...       | 5.0                                  | ...    |
| Total fish per haul | 115.6                                   | 89.8                 | ...                                | ...       | ...                                  | ...    |
| Total fish taken    | 1,618                                   | 1,527                | ...                                | ...       | ...                                  | ...    |

\* Only a small percentage of the spottail shiners were measured. The others were merely counted. The average size given for this species is based on actual measurements.

per cent, of the 404 pumpkinseed from the 16-foot constructions were of legal size, whereas 7, or 2.2 per cent, of the 317 fish from the 8-foot installations were of legal size.

The yellow perch was the most common fish from the 8-foot shelters, where an average of 27 per haul was netted. The bigger shelters produced 24 per haul. The larger number of perch recorded for the small shelters is primarily due to one haul of 171, and most of this particular school of fish were 8 to 9 cm. in length. Another size group of 11 to 12 cm. was also found in the smaller shelters. Only one legal fish was taken from the shelters of each size.

Largemouth bass and smallmouth bass averaged between 1 and 2 fish per haul from either size of shelter. All largemouth bass netted were young fish between 3 and 7 centimeters in length. Of the 26 smallmouth bass caught around the 16-foot shelters, 10, or 38.5 per cent, were legal-sized. From the 8-foot shelters, 6, or 30 per cent, of the 20 fish netted were over 10 inches in length.

The spottail shiner was the most abundant of the forage fishes. Almost 3 fish per haul were taken from the small shelters for every one caught in the larger ones. This difference in populations around these brush constructions is mostly due to one haul from the middle 8-foot, shelter, from which 125, or about one half of the total number of spottail shiners from the small shelters, were netted. The white suckers, although netted in small numbers, were all adults. The sand shiner, caught in limited numbers, was more common in the smaller shelters. The few log perch seemed to show a preference for the larger shelters.

Except for the smallmouth bass a comparison of the average sizes of all species from the small and the large shelters shows little difference.

Five hauls made through the areas between the shelters netted two 16-cm. pumpkinseed, or 0.4 fish per haul, and 74 log perch, or 18.5 fish per haul. The perch averaged 9.3 cm. in length. Two smallmouth bass, 13 and 45 cm. in total length, and one Johnny darter of 3.5 cm. were found in the control seining.

#### CONCLUSIONS AND SUGGESTIONS FOR FISH MANAGEMENT

The conclusions stated here are based on five summers' experiments in providing shelter for fishes in Douglas Lake, Michigan, supplemented by limited earlier work in other lakes by Dr. R. W.

Eschmeyer (Rodeheffer, 1939 : 188). No attempt has yet been made to determine whether such devices will increase the total productivity of fishes in a lake. Rather, the aim has been to ascertain so far as possible the practicability of such constructions and the extent of their use by the various species of fish living in a lake. The value of these conclusions is impaired because we do not know the relative abundance of the various species in Douglas Lake. It may be stated, however, that rock bass, yellow perch, pumpkinseed, small-mouth bass, largemouth bass, and northern pike are present in sufficient numbers (although unquestionably in varying degrees of abundance) to tempt fishermen to angle for these species. Bluegills are not common. In general, fish shelters located in barren parts of a lake attract primarily the young and half-grown fish of certain species (Rodeheffer, 1939). There is a change, however, in such populations by night and by day (Rodeheffer, 1940). If fish are transported from the part of a lake where brush constructions are located, others will repopulate such areas (Rodeheffer, 1940).

More work needs to be done on the effectiveness of fertilizers in the increase of vegetation in and about shelters before definite conclusions regarding this suggested practice can be justified.

Shelters placed in deep water harbor more fish, particularly yellow perch, spottail shiners, and log perch, than those located in shallow water during the warm summer months, although the reverse is true for largemouth and smallmouth bass and rock bass. When shelters are located varying distances apart, those separated by the greater distances support larger populations of yellow perch and rock bass, whereas pumpkinseed are somewhat more abundant in and around shelters placed close together. Likewise, a comparison of the fish populations in and around large and small installations reveals greater concentrations of fish in the larger shelters. This is notably true of rock bass and pumpkinseed. Yellow perch occur in somewhat smaller numbers in the large shelters. -

These studies on the effectiveness and utilization of brush shelters suggest certain conclusions regarding fish management. It is clear that given types of lake improvement will affect the several kinds of game fish in different ways. With full realization that this work covers only one phase of the complex problems involved in the management of lake fishes, the writer now discusses and suggests some of the possible applications, under headings giving the

names of the species that are most commonly taken about the shelters.

#### *Rock Bass*

Young and half-grown rock bass were the most common fish consistently caught in and around the brush constructions placed on the 5- to 6-foot contour in Douglas Lake. However, when the fish from a shelter were transported to another part of a lake the number of rock bass in subsequent seining was always less than that in the first seining. In like manner, the number in night hauls was always smaller than in those by day, and their average size was less (Rodeheffer, 1940). These fish also show the greatest tendency to live at or to return to the same refuge (Rodeheffer, 1941). Shelters placed at a greater depth or located closer together attract fewer rock bass. Small shelters harbor fewer rock bass than large ones.

It should not be difficult to increase the number of rock bass in a lake if this should be desired. Adams and Hankinson (1928:499) found them generally distributed in Oneida Lake and in shallow water, an indication of a preference for areas with abundant aquatic vegetation and stony bottom. Their partiality for cover is well known to anglers and ichthyologists. It has been shown that this species seeks artificial cover in Douglas Lake. It is likely that the number of this fish may be increased in a given body of water by placing adequate brush shelters in the lake, granted, of course, that other conditions, such as spawning facilities, are adequate. If, on the other hand, rock bass are found to be overabundant and stunted, as they are in some northern Michigan lakes, it may be desirable and possible to control their number by destroying their spawning beds, or by giving preferential treatment to other species, by placing artificial shelters in deeper water, and by building small shelters. Or it may be practicable, particularly if other species which are to be encouraged use the same habitat, to build and place these shelters where they will attract the rock bass in great numbers, so that the excess may be taken out for other use by the method of seining employed in the experiments here reported.

#### *Yellow Perch*

Yellow perch were common around all shelters, but the increased concentration around those in deeper water shows that they have

a decided preference, at least during the summer months, for constructions so placed. These fish were found to be more numerous at night, both in shelters and on the open shoals in shallow water, than during the day. If yellow perch were removed from a shelter and transported to another part of a lake, others would move in until the original population was approximately duplicated. Marking of these fish shows that they seem to live in or come back to the locality where first taken during a season. Few were seined there the following summer. Shelters located far apart harbored more yellow perch than those placed close together. It is questionable whether the size of a brush construction is a factor controlling the number of yellow perch that use it as a habitat. If an increase of the yellow perch is desired, such constructions should very likely be placed in deep water. Shelters may be used by perch for spawning or, if it is considered advisable, a brush carpet may be installed for this purpose (Hubbs and Eschmeyer, 1938:83). When these fish are abundant and stunted, as they are in Douglas Lake, control may be aided by limiting the number or by locating shelters in shallow water. If northern pike occur in the lake, placing shelters close together at the depths of weed beds inhabited by pike may attract these predaceous fish into the area, where they may help to keep the perch under control. Seining of the fish around shelters in fairly deep water and destroying those of which there is an overabundance may be helpful. The use of a localized poison, such as rotenone, in killing fish in shelters might also be practicable, provided the shelters do not harbor desirable species that should not be destroyed.

### *Northern Pike*

Northern pike, although abundant in Douglas Lake, were seldom found around brush constructions in either shallow or deep water when they were separated by several hundred feet. Shelters placed close together (50 feet apart) harbored enough pike to permit one to conjecture that, if the encouragement of pike is desired, they should be placed fairly close together and arranged so as to cover a considerable area. It has been observed that the best catches of northern pike by fishermen are generally made close to large weed beds, which, in a barren lake, might be simulated by a concentration of shelters.

*Pumpkinseed*

The pumpkinseed is another game fish that is abundant in Douglas Lake. It shows a decided preference for brush installations, although an unequal concentration is represented around shelters placed in different parts of the lake. In Douglas Lake, North Fish-Tail Bay, with its somewhat quiet water and marl bottom, harbored more young and half-grown fish around the shelters than did other parts of the lake where brush constructions were located. The depth of a shelter seemed to make little difference to fish of this species, but they did prefer those shelters placed closer together. Large constructions make a hiding place for more fish of this species than small installations. As with other species, large numbers desert the covers at night. If they are taken from a shelter and transplanted to another part of a lake, the original concentration will be approached by others coming in.

Provided spawning and other conditions are satisfactory, the pumpkinseed may be encouraged by supplying an abundance of cover, natural (weed beds) or artificial (brush constructions). If possible, a part of a lake, such as a bay resembling a pond with comparatively quiet water, should be chosen.

Control of number should be possible by limiting the shelter available, placing artificial covers in parts of a lake not conducive to pumpkinseed or by destroying the spawning beds.

*Largemouth and Smallmouth Bass*

Not many largemouth and smallmouth bass were taken around shelters in the various parts of Douglas Lake. At Grapevine Point on the lee side of prevailing winds, where the shoals are clean and sandy, the smallmouth bass predominated. In North Fish-Tail Bay, which is partly sheltered, with a bottom composed of sand covered with flaky marl, the largemouth bass were more common. In Bryants Bay, which is more exposed than either of the other two places mentioned, and where the bottom is composed of packed sand, clay, and rocks, largemouth and smallmouth bass were not numerous, but a larger percentage of the smallmouth bass were legal-sized fish. When both species were captured from the shelters and transported to another part of the lake it was found that other fish sought the shelters in numbers about equal to those transplanted. Both large-

mouth and smallmouth bass were seined from shelters and control areas by night and by day, but there were fewer in either place at night than during the day. Largemouth bass, although taken in smaller numbers, revealed a greater preference for the shelters. A larger percentage of marked smallmouth bass were recaptured around the shelters, which indicates a somewhat limited population in such areas.

Neither species displays any particular preference for large or small shelters. Their solitary nature, rather than the size of shelter, may be the controlling element. Smallmouth bass indicate some preference for shelters far apart. Largemouth bass inhabit in about equal number shelters either far apart or close together, but more of them seem to occupy the areas between shelters when they are placed close together. The young of both species were collected in larger numbers in brush installations placed in 5 feet of water than in those placed at a depth of 10 or 15 feet. Environments should be chosen that are well adapted to the species desired. Shelters should be placed in shallow water, and numerous small ones will probably prove more effective than a few large ones, at least for the largemouth bass.

If it should be desirable to control the number of these fish, it is suggested that the amount of shelter be limited or that such constructions be placed in deeper water. The amount of spawning can, of course, also be controlled.

### *Forage Fishes*

Several species of forage fish were taken about shelters in sufficient number to warrant conclusions regarding their use of such structures and to permit suggestions that may be of value in fisheries management. The aim of the experimental work was to test the practicability of improving conditions for game fishes rather than for forage species. It may be possible to construct special devices or to place them so that they will be particularly enticing to individual species of forage fish.

With few exceptions the spottail shiner was taken in small numbers. This probably was due to the fact that most of the constructions were placed in fairly shallow water, on the 5- to 6-foot and 8-foot contours. This fish was found in much larger numbers around shelters placed in 15 feet of water than about those in shallow



water. Small shelters at a depth of 8 feet harbored almost three times as many of these fish as larger shelters similarly placed. From the limited evidence presented it is suggested that small shelters be put in deep water (about 15 feet) and fairly close together (50 feet or less apart), if the aim should be to increase the production of this forage fish.

In Douglas Lake the log perch was found inhabiting shelters placed in 15 feet of water many times more abundantly than those in shallow water. It is questionable what rôle it plays in the welfare of most of our game fishes.

Other species were represented in the shelters. Very few were taken, either because there were not many in the lake or because they preferred some habitat other than that where the shelters were installed.

#### FURTHER INVESTIGATIONS REQUIRED

As experimental work with brush shelters progresses, many additional problems are presented. What kind of shelter is the most efficient, the circular, ladder, hollow-square, single-log, tree, clump, brush carpet, deadhead, stump, stone, tile, or others that may be devised? Are some more desirable for certain species, or for the young or the half grown or the adults of such species? What kinds of brush shall be used in constructing them? Does the water which becomes tea-colored around those made of scrub oak and evergreens become objectionable or even toxic to fish? Should shelters be placed in certain areas fairly close together to resemble large weed beds or should they be spaced at regular intervals along the shores of a lake? Are those anchored on a sharp drop-off more effective than the ones on the shoal? Are artificial constructions superior or inferior to similar natural protection areas (weed beds)? Will they aid in starting aquatic vegetation and, if so, what kinds of shelters are most satisfactory and where, in what part of a lake, and on what kind of bottom should they be placed? Will shelters increase the food supply of fishes and, if they do, what kinds are most satisfactory for this purpose? What effect will the placing of fertilizer in the shelters have on such food production? How long will they last when properly submerged? Thus we may go on with questions that a practical fisheries manager asks when he attempts to improve a lake with such devices.

At present large hollow-center brush shelters lying in parts of Douglas Lake which are under observation are exposed to the prevailing winds. Some of these are supplied with black soil to see whether aquatic vegetation will grow in them. Two unsuccessful attempts have been made to plant aquatic vegetation, and it is hoped that continued observations and, possibly, additional plantings may be made. Spring planting is suggested, for the unsuccessful attempts were made in July and August.

A study of the food growing on or being harbored by shelters seems of vital importance. Such an investigation might show the food available for all sizes of desired species from fry to adults. It may be feasible to develop shelters that will be particularly conducive to the increase of the forage fish populations. In experimental work so far conducted little has been done to introduce improvements for the forage fishes.

Studies of individual lakes with little cover are in progress at present. It is hoped that, when populations are known, such lakes may be improved with artificial shelters to what may be considered ideal conditions. Population studies should then be continued to determine the effect of the shelters on the production of fish.

Many brush shelters and spawning beds have been installed in Michigan lakes since the beginning of 1933. Plans are being made for a careful check of some of these installations to determine their durability and the extent to which they have aided in the establishment of aquatic vegetation and to learn to what degree they are being utilized by fish. Far too little checking of fish management practices has been undertaken.

#### SUMMARY

Experiments in Douglas Lake with brush shelters placed at 5-, 10-, and 15-foot depths indicate that:

1. Shelters at a depth of 15 feet harbor about seven times as many fish as those on the 5-foot contour. The ones at 10 feet offer cover for about twice as many fish as those at the 5-foot depth.
2. Yellow perch are by far the most common fish in the shelters lying in the deeper water.
3. Pumpkinseed inhabit in about equal number shelters submerged at the stated depths.

4. Rock bass show a slight but gradual increase in number as the depth of the shelter is decreased.

5. Young largemouth and smallmouth bass show a preference for shelters in 5 feet of water.

The trials with shelters spaced 50 and 200 feet apart reveal that:

1. Shelters put 200 feet apart protect about 1.5 times as many fish per unit as those 50 feet apart.

2. Yellow perch and rock bass are about twice as abundant in the shelters farther apart.

3. Smallmouth bass are more common in the shelters separated by 200 feet.

4. Largemouth bass are found in about equal number in either group of shelters, but given areas between the closely set shelters produce more largemouth bass than similar areas between the shelters farther apart.

5. Pumpkinseed gather in somewhat greater number in shelters 50 feet apart.

6. Northern pike congregate in larger number in shelters close together.

Data gathered in the work with small and large shelters support the views that:

1. Large shelters harbor more fish than small ones.

2. Rock bass and pumpkinseed are found in greater number around the larger shelters.

3. Yellow perch are more common around the smaller shelters.

4. Largemouth and smallmouth bass are found in approximately equal number around the shelters of each size.

These findings support the conclusions that, if artificial covers are to be effectively used by certain desired species of fish, their placement must vary accordingly. Rock bass prefer large shelters spaced far apart and submerged in comparatively shallow water of about 5 or 6 feet. Pumpkinseed seek large shelters on the quiet, protected shoals, set at any convenient depth but preferably close together. Largemouth and smallmouth bass collect in the large or small shelters in shallow water of about the 5-foot depth. Yellow perch find most desirable small shelters sunk in water about 15 feet

deep, and northern pike seem to seek those which are placed close together.

INSTITUTE FOR FISHERIES RESEARCH  
ANN ARBOR, MICHIGAN

## APPENDIX

### LIST OF SCIENTIFIC AND COMMON NAMES OF FISHES MENTIONED IN THIS REPORT

|                             |                                                     |
|-----------------------------|-----------------------------------------------------|
| Common white sucker         | <i>Catostomus c. commersonnii</i> (Le Sueur)        |
| Northern common shiner      | <i>Notropis cornutus frontalis</i> (Agassiz)        |
| Great Lakes spottail shiner | <i>Notropis hudsonius hudsonius</i> (Clinton)       |
| Northeastern sand shiner    | <i>Notropis deliciosus stramineus</i> (Cope)        |
| Northern brown bullhead     | <i>Ameiurus nebulosus nebulosus</i> (Le Sueur)      |
| Northern pike               | <i>Esox lucius</i> (Linnaeus)                       |
| Yellow perch                | <i>Perca flavescens</i> (Mitchill)                  |
| Northern log perch          | <i>Percina caprodes semifasciata</i> (De Kay)       |
| Central Johnny darter       | <i>Boleosoma nigrum nigrum</i> (Rafinesque)         |
| Iowa darter                 | <i>Poecilichthys exilis</i> (Girard)                |
| Northern smallmouth bass    | <i>Micropterus dolomieu dolomieu</i> Lacépède       |
| Largemouth bass             | <i>Huro salmoides</i> (Lacépède)                    |
| Common bluegill             | <i>Lepomis macrochirus macrochirus</i> Rafinesque   |
| Pumpkinseed                 | <i>Lepomis gibbosus</i> (Linnaeus)                  |
| Northern rock bass          | <i>Ambloplites rupestris rupestris</i> (Rafinesque) |
| Northern muddler            | <i>Cottus bairdii bairdii</i> Girard                |

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## TESTICULAR ASYMMETRY IN THE WOODPECKER *COLAPTES* \*

FREDERICK H. TEST

**E**ARLY in the course of field work to gather material for a study of coloration in the woodpecker genus *Colaptes*, commonly called flickers, I noticed that the left testis differed strikingly in shape from the right. Records were kept of this asymmetry in subsequent collecting, and these form the basis of the present report. Most of the data were collected on field trips sponsored by the Museum of Vertebrate Zoology of the University of California. I am grateful to the director, Dr. Alden H. Miller, for permission to publish these records.

The testes of birds lie opposite to each other, dorsal to the anterior part of the peritoneal cavity and on the ventral side of the elongate, irregularly shaped kidneys. In form the testes vary somewhat from species to species, but most commonly they are approximately oval or ellipsoidal. Van den Broek (1933, p. 96) has indicated the shapes of avian testes as oval (as in the fowl *Gallus*, and other birds), round (as in the sparrow, *Fringilla*), elongate (as in the grebe, *Colymbus*), almond-shaped (as in the bustard, *Otis*), attenuate (as in *Halicus*, a genus I have been unable to identify), and vermiform (as in the swift, *Cypselus*). In most species left and right testes have approximately the same shape. A slight difference has been recorded in pigeons by Riddle (1918), the left being longer and more slender than the right, which usually has a slightly greater bulk. Chapin (1939), in discussing an African woodpecker of the genus *Campithera*, says ". . . the left testis, which is apt to be slightly larger, often exhibits a very unusual shape, being bent abruptly outward at the anterior end." He found this condition in several specimens of four species (two races of one) belonging to this genus, and he notes that he has seen a similar condition elsewhere only in *Colaptes auratus*.

Most of my records refer to the Red-shafted Flicker (*Colaptes*

\* Contribution from the Department of Zoology, University of Michigan.

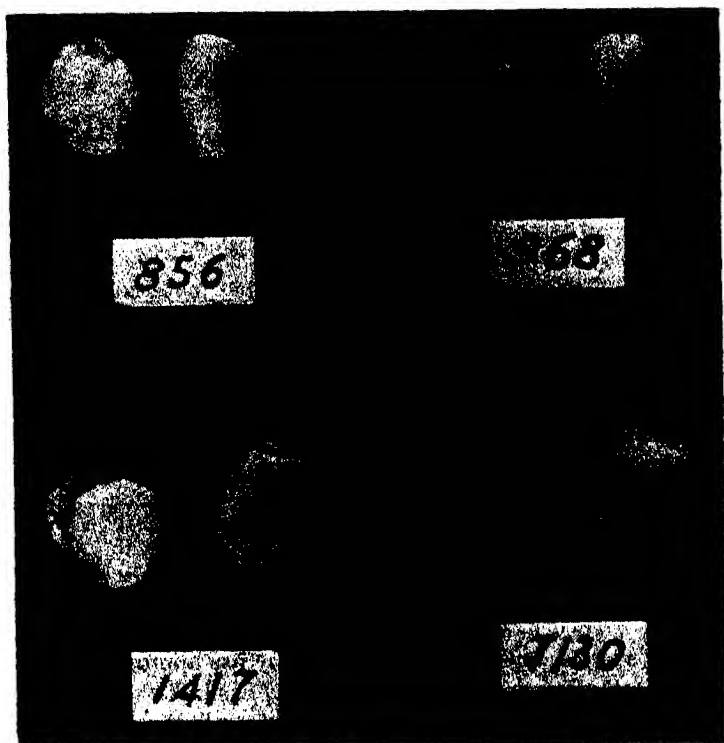


FIG. 1. Pairs of testes from four breeding individuals of *Colaptes cafer*, showing some of the typical variation in form.  $\times 1\frac{1}{2}$

*cafer*). In this species the right testis in the adult (Fig. 1) is approximately oval or elliptical in outline. The left testis usually has a smaller short dimension and is about half again as long, tapering to a blunt point anteriorly. The anterior half or less of the left testis extends laterad, forming a considerable angle with the posterior part, which lies approximately parallel to the long axis of the body. Occasionally there is a constriction at the bend. Table I shows that in thirty-one left testes from breeding birds for which I have adequate data the bend is a 90-degree angle in most of the birds. Two specimens have only a small laterally projecting process on the anterior end. One (Fig. 2, No. 985) shows no angulation, being elliptical in outline, a little longer and more slender than its mate.

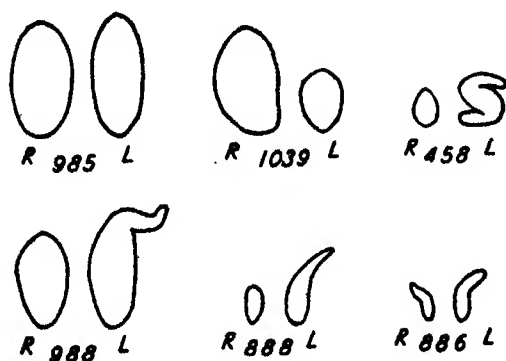


FIG. 2. Outlines of pairs of testes from six specimens of *Colaptes*. *C. cafer*: adults, nos. 985, 458, 988; juveniles, nos. 888 and 886. *C. auratus*: adult, no. 1039.  $\times 2$

Another gonad (Fig. 2, No. 458) is unique in that it forms a sharply bent S. In two of the gonads with a 90-degree bend the anterior tip is bent forward at a large angle to the laterally projecting segment (Fig. 2, No. 988).

TABLE I

ANGULATION OF THE LEFT TESTIS IN *COLAPTES*

| Birds                              | No angulation | < 45° | 45° | 50-85° | 90° | Total records |
|------------------------------------|---------------|-------|-----|--------|-----|---------------|
| <i>C. cafer</i>                    |               |       |     |        |     |               |
| Breeding adults .....              | 1             | 1     | 2   | 2      | 25  | 31            |
| Nonbreeding adults ....            | 0             | 4     | 7   | 0      | 5   | 16            |
| Juveniles .....                    | 0             | 0     | 3   | 0      | 0   | 3             |
| <i>C. auratus</i>                  |               |       |     |        |     |               |
| Breeding adults .....              | 1             | 0     | 3   | 0      | 3   | 7             |
| Nonbreeding adults ....            | 0             | 0     | 1   | 0      | 1   | 2             |
| Juveniles .....                    | 0             | 1     | 2   | 0      | 0   | 3             |
| <i>C. chrysoides</i> , adult ..... | 0             | 0     | 1   | 0      | 0   | 1             |

Table I also shows that sixteen left testes from adult nonbreeding flickers average somewhat different in form, the largest number having an angulation of about 45 degrees. This suggests that the annual growth of the testes preparatory to breeding commonly



causes the left one to become more sharply angled than it is in the quiescent condition of winter.

I have few records for juvenile Red-shafted Flickers. Each of the three available has an angulation of about 45 degrees (Fig. 2, No. 888), showing that the asymmetry of the testes is present at least as early as the fourth week after hatching. Two of these juveniles have the right testis, as well as the left, turned outward at the anterior end, but only the tip is turned, and the whole gonad is decidedly shorter than the left one (Fig. 2, No. 886).

In bulk the left testis is usually somewhat smaller than the right. The volumes of four typical pairs of testes of breeding birds, determined by displacement of liquid, are shown in Table II.

TABLE II

VOLUMETRIC COMPARISONS IN CUBIC CENTIMETER OF RIGHT AND LEFT TESTES OF *COLAPTES CAFER*

|                    | No. 928 | No. 967 | No. 945 | No. 1417 |
|--------------------|---------|---------|---------|----------|
| Right testis ..... | 0.40    | 0.20    | 0.27    | 0.35     |
| Left testis .....  | 0.30    | 0.20    | 0.22    | 0.40     |

The fewer records available for the eastern yellow-shafted flicker (*Colaptes auratus*) present a picture similar to that just described. In seven breeding adults (Table I) the left testis had an angulation of about 45 degrees in three and of 90 degrees in three. A single bird (Fig. 2, No. 1039) had an oval left gonad, like that of the right side but considerably smaller. Of the two records for nonbreeding adults one shows a left testis with a 45-degree angle; the other, a 90-degree bend. The three available records for juveniles are of an angulation of 45 degrees or less.

A single record for a nonbreeding Gilded Flicker (*Colaptes chrysoides*) exhibits a left testis bent outward at a 45-degree angle.

#### DISCUSSION

It is pertinent to ask whether the asymmetry described above is inherent in the gonads and their *Anlagen* or whether it is a result of environmental factors. Material is not at hand for a study of the morphogenesis of flicker testes, but a few suggestions and obser-

vations may be recorded here. The left testis was longer than the right in all but one of the specimens examined, which would suggest that this asymmetry is inherent, although its primary cause is not indicated. The bending laterad of the anterior end of the left gonad, however, is occasionally absent and is commonly variable in degree. This indicates that the environment of the developing testis may be, in part, responsible for its final shape.

In the chick the genital ridges differentiate just posterior to the origin of the vitelline arteries and near the mid-line of the body, in fact, immediately laterad to the dorsal mesentery. It is probable that these ridges form in a similar location in *Colaptes*. A logical explanation for the bent testis thus seems to be that the germinal epithelium differentiates so far forward on the left side as to include some of the tissue on the posterior side of the base of the vitelline artery. The growing gonad would then of necessity come to assume the same curve or angle as that between the vitelline artery and the posterior part of the dorsal aorta. That the right testis usually is not curved probably is due to a shorter genital ridge which does not extend as far forward as the vitelline artery. In this connection it seems important to note that the posterior ends of the two members of each pair of testes in the juvenile and adult flickers I have examined were at approximately the same anteroposterior level. Being longer, the left gonad thus had its anterior end well ahead of that of the right, and there is no apparent reason for believing that one has migrated in relation to the other in the course of development.

It is evident from Table I that, as pointed out before, the left testis assumes a more sharply angled form as it enlarges preparatory to the breeding season. The explanation for this change may be completely environmental, a result of the growing testis pushing against some relatively unyielding organ anterior to it and being forced to assume a right-angled bend. The testes are situated near the anterior end of the peritoneal cavity, and the organs there are considerably crowded and unyielding. Unfortunately, no data are at hand to prove or to disprove this hypothesis. Another possible explanation suggests itself. There may be a difference between the inner and the outer curvatures of the left testis such that the greater curvature undergoes a greater increase in length in the enlarging testis than the lesser curvature does. Such a difference might be

in the tension of the tunica albuginea or of the covering peritoneum. The result would be a change in curvature as the gonad enlarges.

As Friedmann (1927) has suggested, it seems probable that normal testicular asymmetry has no relation to a disturbed sex ratio. Riddle, in 1918, published observations on pigeons which correlated a sex ratio in favor of the male, with a testicular asymmetry in offspring resulting from interspecific and intergeneric crosses and also in some diseased individuals. In these birds the left testis was larger than the right oftener than in healthy birds from intra-specific matings. This, however, is a very different thing from the usual and normal occurrence of asymmetry in wild populations.

A distinct asymmetry such as that described above may prove to be of value in establishing additional evidence of phylogenetic relationships. This is dependent, of course, on the cause of the asymmetry, whatever that cause may be, being inherited. So far as is now known, this type of asymmetry is confined to the woodpeckers (Picidae). It occurs in genera other than *Colaptes* and *Campthera*, but too few data are available to enable me to judge its incidence accurately. Field sketches are at hand for male gonads of one Red-breasted Sapsucker (*Sphyrapicus varius*), three Downy Woodpeckers (*Dryobates pubescens*), two Hairy Woodpeckers (*Dryobates villosus*), and two California Woodpeckers (*Balanosphyra formicivora*). In one individual of each of the last two species the left testis was longer and curved slightly laterad in the anterior part. All others were symmetrical.

Here is a problem on which field collectors could gather a large amount of information incidental to their main objectives and with little loss of time. It is routine with many collectors to measure one testis as an indication of breeding condition. Because of the asymmetry in some species, a record of whether the left or the right testis is measured should always be kept. Little additional time would be consumed if an outline, to scale, of both testes were sketched in the field catalog.

The author is grateful to Dr. A. E. Woodhead for assistance in making the photographs here reproduced.

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# THE VALUE OF MUSSEL DISTRIBUTION IN TRACING STREAM CONFLUENCE

HENRY VAN DER SCHALIE

## INTRODUCTION

THE application of the distribution of mussels in streams to geomorphic problems has been a controversial subject for the past fifty years. The disagreement rests mainly on the interpretation of established facts dealing with the life history, ecology, and distribution of these animals. So far as I can judge from the historical development of this controversy, there are mainly two groups: (1) a few geomorphologists and workers in other fields who follow Johnson (1905) in the contention that stream confluence is but one of several ways by which fresh-water mussels have managed to go from one drainage basin to another; and (2) several malacologists, including some of our best students of the naiades, such as the late Dr. A. E. Ortmann and Dr. Bryant Walker, who have attempted to show that confluence is essentially the best explanation for the natural distribution patterns found at present.

Considerable difficulty has resulted in the course of the controversy because of confusion in regard to the specific group of shells to which we are limiting ourselves. In order to keep the issue clear and to arrive at any sensible evaluation of the relative merits of the evidence presented, it is important at all times that we realize that we are concerned only with fresh-water mussels and not with the gastropods or the Sphaeriidae that may be found with them. It is generally known that small isolated bodies of water will often in some unknown manner become populated with snails and fingernail clams. Just how this populating takes place is as yet largely a matter of speculation, and considerations of these questions, along with the

EDITOR'S NOTE — In 1943 this paper won first place in a competition for the Walker prizes in natural history sponsored by the Boston Society of Natural History. Contests are held annually. It was the intention of the founder of the fund, the late William Johnson Walker, to encourage the younger research workers in their investigations. E. S. McC.

evaluation of naiades as indicators of stream confluence, invariably lead to confusion and muddle our thinking. At the outset, then, it is necessary to stress the condition that we have to do with but one group of animals, the mussels, which are highly specialized biologically and tend to behave in a very characteristic manner in matters pertaining to their life history, ecology, and distribution. These facts have been well established, and it is largely because we have some sound and basic biological concepts within this group of animals that we can use the evidence presented to good advantage in tracing former stream connections.

#### HISTORY OF THE CONTROVERSY

The controversy began shortly before the turn of the century. Hayes and Campbell (1894), in a discussion of the geomorphology of the southern Appalachians, called attention to some geological and physiographical indications to support their theory that the Tennessee River formerly flowed southward to the east of the present Walden Ridge and, following a path across a low divide into the present Alabama River system, emptied into the Gulf of Mexico. They suggested that a tributary of the Sequatchie River cut through Walden Ridge near the close of the Tertiary period and tapped the headwaters of the Tennessee, causing it to flow due west, as we now find it.

Biologists soon lent support to this theory. Simpson (1900) gave credence to the hypothesis on the strength of the distribution of mussels common to both the Alabama and the Tennessee rivers. A year later Adams (1901) offered additional faunal evidence which he believed essentially indicated that a former connection existed between these two major drainage systems. He stressed the supposition, however, that sufficient time had elapsed to permit specific differentiation between the animals of these rivers.

In 1904 Johnson spent two weeks in the Chattanooga district to evaluate the physiographic and geologic evidence for such a confluence. In a thesis published a year later (1905) he said:

In summing up the evidence which has been presented in favor of the theory of a recent westward diversion of the Tennessee from a former southward course, it has been pointed out that while the facts noted in that connection admit of a rational interpretation on the basis of capture, they are to be explained just as readily and satisfactorily entirely independent of that theory.

It is possible that this statement constitutes a sound physiological interpretation. Nevertheless, the faunal evidence implies that there had been a confluence between the Tennessee and the Alabama rivers. Johnson (1905) attempted to show that Simpson's faunal evidence was not satisfactory by pointing out that the distribution of certain species he used to prove such a confluence was contradictory. Actually, so far as the argument is concerned, Johnson appears to have the better of the situation. Fortunately, in science only *facts* are acceptable. As a pioneer Simpson was all too ready to speculate on distribution patterns that were not well established. More thorough students would certainly not subscribe to some of his statements, much less to certain of his speculations which claim that birds are important passive agents in the extension of the distribution of naiades.

In 1913 Ortmann published his paper on the influence of the Alleghenian Divide upon the fresh-water fauna. The introduction to this work referred to the "Tennessee-Coosa" problem. Although he devoted only a footnote to the controversy considered here, he summarized his stand in this issue so well that it deserves a complete statement:

This is the problem in which Johnson (1905) is especially interested. The old idea is (see chiefly Hayes, 1899) that the headwaters of the Tennessee once continued in the direction of the Coosa (*Appalachian River*), and that the present course of the Tennessee is due to a deflection in consequence of stream capture. Johnson believes (and also White, 1904) that the present course of the Tennessee is original, and I consider his physiological evidence as perfectly sound and satisfactory. But since the Najades (and other freshwater groups) have been used to demonstrate the correctness of the assumption of the existence of the Appalachian River (see Simpson, 1900b, p. 133, Adams, 1901, p. 846, and Ortmann, 1905, p. 130), we must take cognizance of this line of evidence, and dispose of it in some way. Johnson did this by dismissing it as not convincing, as not apt to demonstrate stream capture. However, as I have said, he is wrong in this, and I believe the distribution of the Najades *does indicate stream capture in this region*, but in the opposite direction: the original fauna belonged to the old Tennessee (similar to the present in its course), and certain southern tributaries of it have been captured by the Coosa-Alabama system. This idea is already implied in Simpson's (1900b, p. 135) sentence: "It is probable that nearly all the Unionidae of the Alabama River system have been derived from the Tennessee," and White (1904, p. 38) directly says that the upper course of the original Walden Gorge River (tributary to Tennessee) has been captured by Conasauga River (tributary to Oostanaula and Coosa Rivers.)

We must emphasize that Ortmann did not question Johnson's evaluation of the physiological evidence, but he was nevertheless



convinced that the distribution patterns of the mussels in this critical region show that *stream confluence* has taken place. The exact place and method may be open to question, but there is factual evidence to indicate that the Tennessee and the Alabama rivers were once connected.

Unfortunately, Ortmann and Johnson did not pursue this issue further. The matter rested till 1938, when van der Schalie (1938b) published the results of a study of the mussels of the Cahaba River in northern Alabama. This work again suggested that there were formerly connections between these major drainage basins. The general conclusions drawn from the facts presented were as follows:

It seems necessary to conclude that in geologically recent time tributaries of the headwaters of the Alabama drainage were connected with tributaries of the Tennessee drainage. This confluence permitted the three creek species known to belong to the Tennessee drainage to enter the headwaters of the Alabama drainage.

The seven representative species which entered the Alabama River system from the north by way of the Tennessee drainage indicate that streams somewhat larger than creeks were connected. Since these forms are at present more or less differentiated in the two river systems, sufficient time must have elapsed to permit differentiating evolutionary tendencies. Thus, the connection of the larger streams must have preceded that of the creeks.

These pronouncements brought an immediate response from Johnson (1939), who suggested that they avoided the main issue, which, according to him, is: "Do these mussels require fresh-water connections between two streams in order to pass from one to the other?" An answer to this question was given by van der Schalie (1939a) in an article which stressed the following important considerations:

1. In spite of the series of published records by naturalists on observations of fresh-water mussels attached to the feet of aquatic birds, "no one has ever established that fresh-water mussels *have actually been transported from one stream to another in this manner.*" When this matter was brought to the attention of Dr. H. A. Pilsbry at a meeting some time later, he suggested that we failed to note an important point in this connection, that is, that the birds seen with mussels attached to their feet were crippled or dead birds, and he did not feel that such birds were important distribution agents.

2. Another strong piece of evidence against the distribution of mussels by birds is the fact that most species have "a characteristic

distribution pattern within one or more of the major drainage systems. Such patterns would not be likely to develop if mussels were haphazardly carried about from stream to stream by birds."

3. Life-history studies indicate that naiades are a unique group. "Protagonists of passive migration of mussels by means of aquatic birds fail to take into account the life-history requirements of our Naiades. All North American fresh-water mussels are parasitic in their larval stage on some species of fish before they are capable of beginning life in the environment in which we find them."

4. Many species of mussels are highly specific in their ecological demands. "Assuming that a mussel which accidentally attached itself to the foot of an aquatic bird were a gravid female, and that that mussel with its potential glochidia (also an assumption because glochidia are shed at specific periods) reached a body of water belonging to another drainage, it would yet not necessarily establish a colony of mussels there, because the particular fish host which carries that particular species of mussel would necessarily have to become parasitized to complete the life cycle of the mussel. Also, even if one assumes that all this did happen by chance, the ecological demands for most species of mussels are such that the young mussel dropping from a fish would have to arrive in an environment suited to it, a condition which adds materially to the hazards involved."

5. Finally, there is an abundance of evidence to show that the very regions where malacologists find a "mingling" of mussel species are also the areas in which geologists and physiographers have given facts to prove the existence of zones of confluence. Attention was called to the presence of such areas in:

(a) Michigan, Ontario, and New York, where postglacial waters connected the Mississippi and the St. Lawrence rivers;

(b) The region of the upper Red River of the North, where a confluence permitted certain Mississippi naiades to enter the waters flowing north to Hudson Bay;

(c) The zone mentioned by Simpson (1893) as "the southern end of the mountain range," which presumably refers to the supposed connection between the Tennessee and the Alabama rivers;

(d) Finally, the region of Yellowstone Park, where a confluence appears to have occurred between the headwaters of the Missouri and the Snake rivers over a divide known as Two-Ocean Pass.

The confluences just mentioned are merely the ones most generally recognized among malacologists and geologists as important and clearly defined connections with an attendant influx of species. Others will be mentioned later in this paper.

The preceding contentions by van der Schalie were considered in some detail by Johnson (1941, 1942). Unfortunately, his involved hypothetical discussions failed to take into account published information giving several definite distribution patterns. These patterns cannot be explained at present unless we recognize that well-authenticated biological facts force us to rely on the evidence that mussels are carried across divides by fishes during a period of confluence. Reference will be made later to these unfortunate omissions of factual information. As a result of a mere suggestion that confluence is not the only method by which mussels manage to cross drainage divides, we should not, then, assume that the basic work of able malacologists such as Simpson, Ortmann, and Walker is of no significance in the solution of problems involving former drainage. Johnson's statements, nevertheless, imply as much. In the light of what is known it seems unwarranted and foolish not to give the zoogeography of naiades at least fair consideration.

It is possible that additional geological information will soon be available to aid in the solution of the Tennessee-Alabama drainage problem. A communication from Edwin C. Eckel, chief geologist for the Tennessee Valley Authority, contains the following statement:

"We have in preparation right now a very large report — probably some four to five hundred pages — on the regional geology of the dams. To that I am prefixing a summary of the more important features of the region, and in that summary I am giving some space to consideration of the geologic history of the river itself."

Since we are forced by the involved nature of this drainage problem to await further evidence for its solution, may I suggest that we turn to the Michigan area, where the present drainage systems have been established in comparatively recent time? The main events in the postglacial development of the rivers in this state have been well determined by careful studies of a number of competent geologists. Certainly there is no conflict among them and geomorphologists regarding postglacial drainage in Michigan like that found in a region as complex historically as the Gorge in

Walden Ridge. In fact, it seems sound for us to consider post-glacial drainage changes here and their relations to mussel distribution in the nature of a laboratory test to determine whether basic correlations actually exist between confluence and the distribution patterns of the naiades. If there are strong indications that confluence is the usual and most effective means to establish the distribution patterns of mussels, it would seem essential to guard against giving unwarranted weight to other hypothetical means of dispersal among this specialized group of animals. Furthermore, if we are to accept a precept fundamental in geology, that we interpret the past in terms of the present, it is imperative that we give due consideration to the logical method for the dissemination of these animals, particularly when in nature a series of well-established events are correlated so convincingly.

#### DISTRIBUTION OF NAIADES IN MICHIGAN

##### *Southeastern Michigan*

It was in southeastern Michigan that students of naiades first noticed the importance of confluence in relation to mussel distribution. It is a striking fact that practically all the sixty species in this area are a Mississippi River assemblage and not, as one might normally expect in a consideration of present drainage conditions, members of the group of species common to the lower St. Lawrence River. Walker (1913) expressed the opinion, now widely accepted, that the "pre-glacial fauna of the St. Lawrence system was absolutely exterminated during the glacial period." He also stated that the Mississippi fauna now found in Lake Erie consists of "post-glacial immigrants from the south and [is] not the result of any survival in that region of any part of the pre-glacial fauna." According to him, the present fauna in Lake Erie is due to an invasion from the Mississippi Valley through the Maumee River outlet into post-glacial Lake Maumee.

Ortmann (1924) elaborated upon this invasion and showed that a particular stage in the postglacial lake development is of great significance in accounting for contemporary naiad distribution in the present tributaries of Lake Erie. He proved that three distinctive river species of mussels in those tributary streams in northern Ohio are not found in Lake Erie itself, and yet these same three species occur in the Maumee River. This condition is generally known as

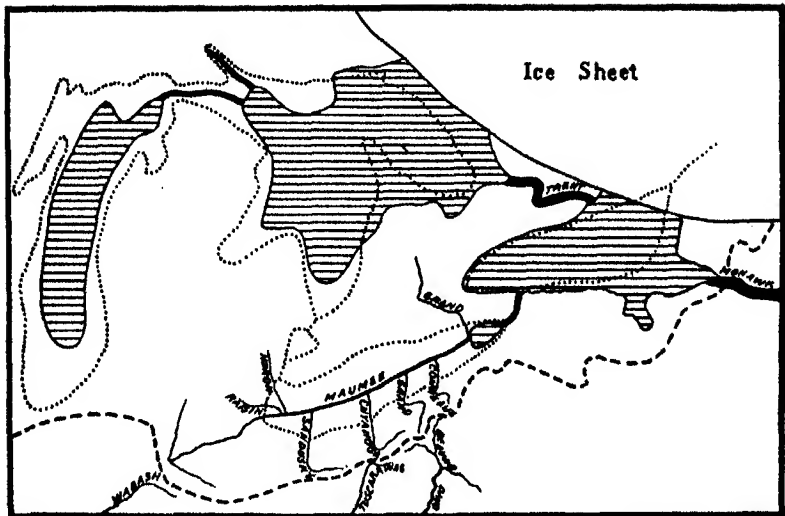


FIG. 1. Trent outlet stage of the Great Lakes

discontinuous distribution. By recourse to postglacial history of the region Ortmann was able to show (see Fig. 1) that during the Trent-Nipissing stage the water of the later Algonquin and early Nipissing Lake periods did *not* flow into the Lake Erie basin and that this region was almost free of impounded water, with perhaps only a remnant of the lake at the eastern end of the basin near Buffalo. These conditions permitted the Maumee River to continue through the partially dry bed of Lake Erie, and thus make the present tributaries to Lake Erie tributary to the Maumee River itself. In this way a *continuous* river pattern was established. When, at the end of the Trent outlet stage, the rising continent caused the reappearance of Lake Erie, the present *discontinuous* pattern was set for the three river-inhabiting mussels (*Alasmidonta marginata*, *Actinonaias carinata*, and *Lampsilis fasciola*).

Later, van der Schalie (1938a) showed that these same three species occur in the Clinton, Huron, and Raisin rivers of south-eastern Michigan, and thus confirmed the prediction already made by Ortmann (1924), who suggested that the Huron and Raisin rivers were also a part of that Greater Maumee River system. In addition, van der Schalie (1938a) called attention to the fact that

none of these three "river" species is found in the River Rouge. Consequently, it was postulated that that drainage is "of more recent origin and has been formed since the return of the waters to the Lake Erie basin at the end of the Nipissing-Trent Lake stage in a change which caused the formation of the modern Great Lakes." Since Rouge River is confined largely to a low plain of lacustrine sand, it is not unreasonable to assume that it is topographically younger than the Clinton, Huron, and Raisin rivers. It is probable that the Rouge was never connected with the Greater Maumee, but it must be emphasized that the evidence thus far is based entirely on the distribution of the mussels it contains.

These brief statements on naiad distribution of the southeastern region of Michigan as it was brought about by confluences that occurred during the postglacial period demonstrate how closely the facts relating to the biology of this group of animals are connected with the glacial and geomorphic history of this area. There may be some who would prefer to explain these facts of distribution by any agent at all other than certain species of fish that normally carried particular species of mussels during periods (perhaps many years) when confluence existed. If we assume that birds were instrumental in effecting naiad distribution, it seems unlikely that such a striking correlation of events would exist, especially since there is reason to believe that the distribution of mussels by birds is haphazard and fortuitous. Explanation of mussel distribution on the basis of any passive agent other than the natural one (fishes) becomes even more unreasonable when we note that the ecological demands of certain species of mussels are such as to exclude them from a lake environment.

### *Southwestern Michigan*

Van der Schalie (1941) recently published the results of zoogeographical studies conducted in southwestern Michigan. Considerable factual information was contained in tables used to show the distribution of the mussels in both the Grand and the Muskegon rivers (Fig. 2). Reference was made to the generally accepted belief that the Mississippi fauna arrived in that portion of the state at the time of confluence between the streams of that region and the Mississippi drainage by way of the Des Plaines River and the Chicago outlet to the Mississippi River. Not only does the distri-

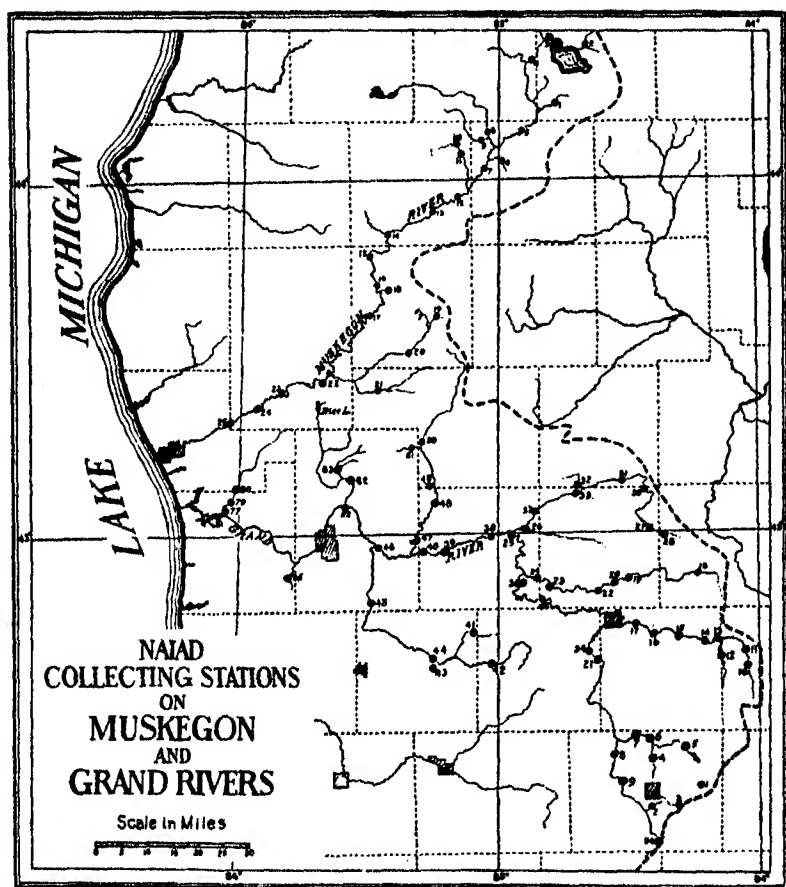


FIG. 2

bution of the fauna as a whole suggest that this assumption provides the most plausible explanation, but detailed information on the relation of the mussels in the Muskegon River to those in the Grand River indicates "that at one time in its drainage history the Muskegon River was a tributary of the Grand River. This view is substantiated by the glacial history of these streams, since it is known that the Muskegon River was at one time connected with the Grand River through the valley of the present Rouge (Rogue) River."

In the same paper van der Schalie stated that he was fully aware that "considerable skepticism exists among zoologists, geologists, and physiographers regarding the value of distributional studies of naiades in tracing stream confluence." In order to show how difficult it is to explain certain distribution patterns in any other way he cited the following examples:

A common mussel of southwestern Michigan is *Actinonaias ellipsiformis*. It was found at many stations in the Grand River . . . . On the other hand, *Lampsilis fasciola* is well represented in the three main rivers of southeastern Michigan . . . . Both species inhabit rivers, are associated ecologically with streams of medium size, and usually are not found in the Great Lakes. Hence both are at present *discontinuous* in their respective ranges. The distribution

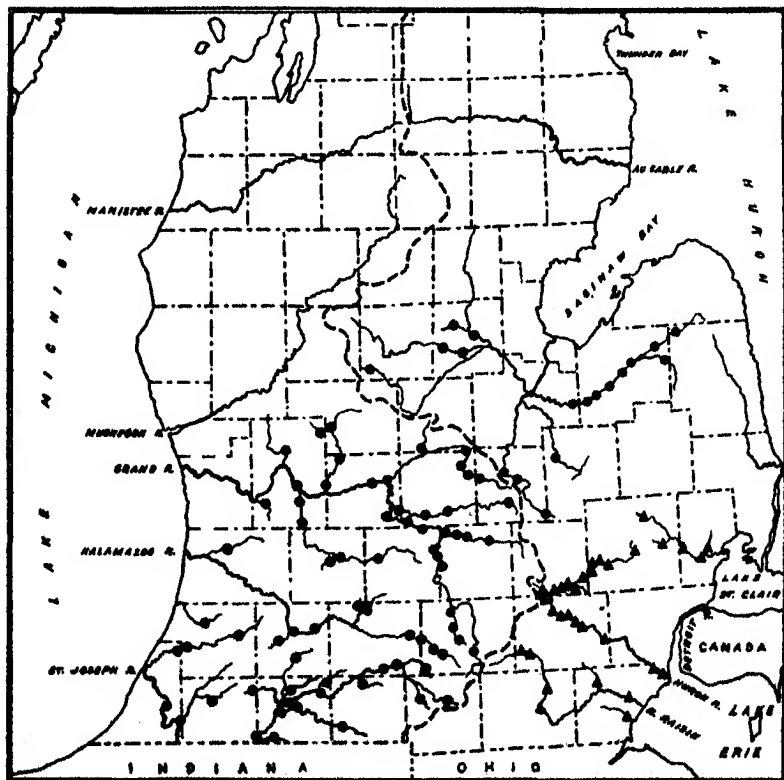


FIG. 3. Distribution of *Actinonaias ellipsiformis* (circles) and *Lampsilis fasciola* (triangles) in southern Michigan



pattern of each is shown graphically in Figure 1 [Figure 3 in this paper]. If naiades are distributed by birds and mammals, it would be interesting to have an explanation of the reason why neither of these species, *ellipsiformis* and *fasciola*, has been carried across the east-west drainage divide, particularly since the tributary streams of the two major drainage systems so closely approximate each other. Dr. Wilbert B. Hinsdale (1931, p. 6), in discussing famous portages in Michigan, points out that only a low divide separates the Raisin River from both the Kalamazoo and the Grand rivers. In regard to the divide between the Huron and the Grand rivers he says: "Mr. N. F. Wing, of Grass Lake, states that forty years ago he actually paddled across the divide between Portage River and Otter Creek, through the lowlands and swamps, without having to get out of his canoe. During high water the Indians certainly could have done the same thing; the only obstructions from Lake Erie to Lake Michigan would have been rapids and fallen timber." Nevertheless, owing to restrictions attending the ecology and distribution of naiades these species have not crossed this divide since glacial time. Certainly if birds and mammals are a factor in mussel distribution, such a restriction would not be likely to persist.

When the distribution of the species mentioned above is considered in relation to the late glacial history of the drainages inhabited by them, a remarkable set of correlations is evident. The rôle of glacial history in the distribution of *Lampsilis fasciola* has already been discussed . . . . Consequently, only the conditions affecting the distribution of *Actinonaias ellipsiformis* will be considered at this time. It not only occurs in all the rivers on the west side of the state south of and including the Grand, but has also entered the tributaries of the Saginaw drainage basin . . . . This pattern of distribution is to be expected in view of present knowledge concerning the confluence that formerly existed between the Saginaw and Grand River drainages. According to Russell and Leverett . . . , that connection persisted while Lake Warren discharged its waters across the Saginaw-Grand divide. This confluence accounts for the invasion of the Saginaw River drainage by *ellipsiformis* and other river-inhabiting species of mussels. No explanation has yet been advanced, however, for the absence of *ellipsiformis* in the Muskegon River drainage. Both *Actinonaias carinata* and *Alasmodonta marginata* probably entered the Muskegon during the period when the Grand and Muskegon rivers were connected, as has already been discussed. The fact that *ellipsiformis* did not enter the Muskegon simultaneously may mean that it invaded the Grand River drainage at a period when the connection between that river and the Muskegon no longer existed, but before the severance of the confluence between the Saginaw and Grand River drainages.

### Northwestern Michigan

In 1939 van der Schalie (1939b) reported investigations carried out in the Menominee-Dickinson region adjoining Green Bay. The distribution of certain mussels of the area shows that Mississippi River naiades invaded the St. Lawrence drainage basin in this portion of the Upper Peninsula. The matter was treated in sufficient detail to bring out for the area a basic correlation between established facts in mussel distribution and the connection that formerly existed between the Fox River and the Wisconsin River at Portage, Wis-

consin. Once again detailed information concerning the ecology and distribution of the mussels implies former drainage patterns which geologists have not yet fully uncovered. That the early drainage in Green Bay and the upper portion of Lake Michigan was different from the present one is suggested in the following statement:

In order to account for the presence of such river-inhabiting species as *Actinonaias carinata* and *Alasmidonta marginata* in the Menominee drainage basin, there must have been a continuity of river conditions throughout the Fox River Valley. Major difficulties in the way of this would have been the presence of lakelike regions such as Green Bay and Lake Winnebago. Leverett suggested that if we allow some seventy-five feet for tilting in the Green Bay region, there is a likelihood that the southern end of Green Bay and perhaps the bed of Lake Winnebago, which has a maximum depth of but twenty-one feet . . . , may have been nonexistent, and an ancient Fox River might have flowed in a north-eastern direction through this bed.

These facts also have recently been supported by some geologists and physiographers, as was indicated by the following series of statements:

The details connected with the matter of bringing the Menominee drainage in conjunction with the Wisconsin River by way of the Fox River Valley are not simple. According to Martin . . . , there were two rivers in the present Fox River Valley. The one, which was active during the glacial period, is still represented by that portion of the present Fox River drainage extending from Lake Winnebago to the headwaters of the Fox River at Portage [Fig. 4]. This region has the unusually small gradient of only one-half foot per mile. Such a gradient in the headwaters of a stream becomes significant when we consider that it is less than the gradient in the Mississippi River itself. In contrast to the flat grade of the upper Fox, the lower Fox River, extending from Lake Winnebago to Green Bay, drops on an average of five feet per mile. This represents a later development than that in the headwaters, and it may have some connection with the drop in lake level which Stanley (1938: 972-74) has described as occurring during a low stage in the Lake Algonquin level. The waters of Lake Michigan and Green Bay are reported to have subsided as much as 150 feet. In another paper . . . Stanley claims that the lake level may have dropped as low as 200 feet below its present level in the Green Bay area.<sup>1</sup> At present the depth in Green Bay opposite the mouth of the Menominee River is 114 feet. Consequently, there is no question but that the low-water stages during the Algonquin period were sufficient to give a dendritic river pattern which would have connected the lower Menominee with the greater Fox River flowing through the valley of Green Bay. In this connection, it is of interest to note that on the basis of soundings in Green Bay there is evidence that remnants of a former river valley exist in the bed of this bay. A number of other streams, including the Peshtigo and Oconto rivers in Wisconsin and the Ford, Escanaba, Whitefish, and Sturgeon rivers in Michigan, might have also been connected to form this greater Fox River system.

<sup>1</sup> Dr. Stanley has not yet published this paper, but he has orally confirmed the information.

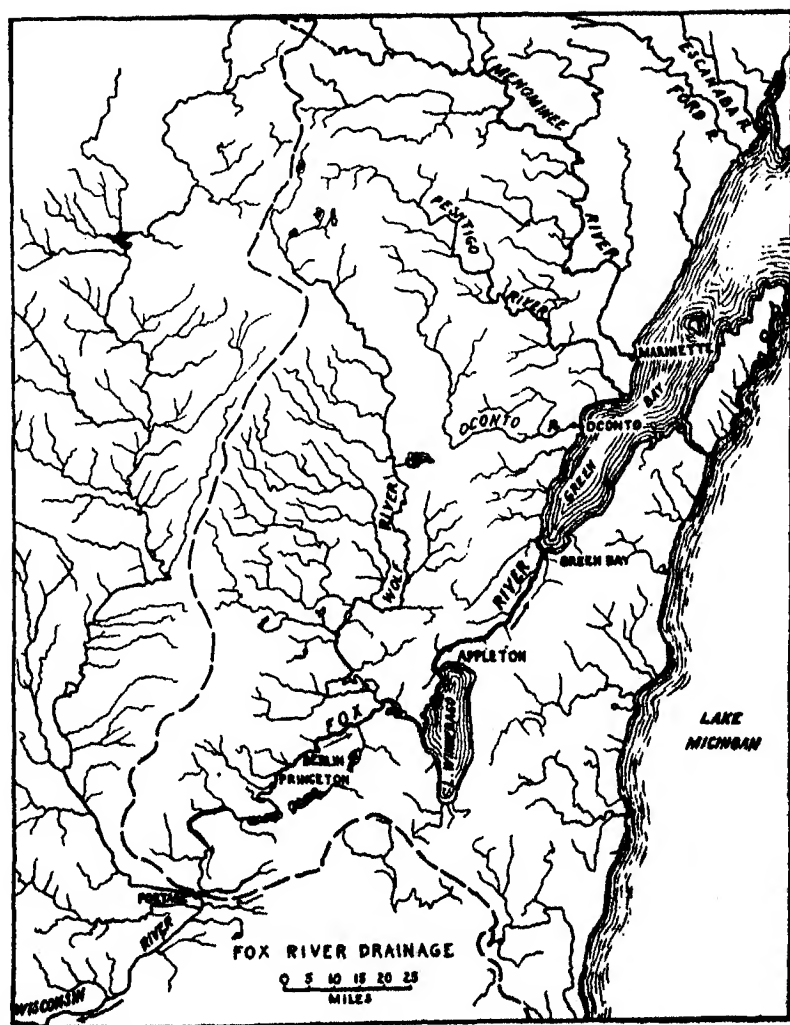


FIG. 4. The Fox River drainage basin

#### THE PROBLEM OF DISREGARDED FACTS

The brief consideration of these three major zones of confluence in the preceding survey of areas in Michigan by no means represents

an exhaustive study of the problems involved. It is clear, however, that a sizable quantity of factual information is available on the biology of fresh-water mussels and that this information can serve as evidence in evaluating the significance of the naiad distribution for tracing stream confluence. Johnson (1941, 1942) apparently avoided taking into account the *facts* which will remain altogether unexplained unless we assume that mussels are carried across divides in the natural manner, that is, as larval parasites on fish. Numerous quotations were used in the preceding section largely to emphasize that there are, contrary to Johnson's specific charge, publications giving well-established patterns of distribution. He stated in 1942:

It is unfortunate that van der Schalie gives only two short sentences to what he considers "perhaps the strongest evidence against the distribution of mussels by birds." We have only his statement that "most species of mussels have a definite and characteristic distribution pattern within one or more of the major drainage systems," and an expression of his personal opinion that "such patterns would not be likely to develop if mussels were haphazardly carried about from stream to stream by birds." Since these contentions go to the very root of the question at issue, it would seem that any discussion of the problem should include an adequate summary of the facts of field evidence, a clear explanation of their supposed significance, and a comprehensive statement of the reasoning based on them and the conclusions reached.

It is unnecessary to consider Johnson's (1941, 1942) long analytical discussion of the theoretical implications involved in the use of mussels as indicators of drainage change because his discussion assumed that we lack facts from which to draw conclusions. Certainly there is no objection to a difference of opinion concerning the conclusions derived from substantial factual information. It seems reasonable to expect, however, that if one disagrees with the deductions made from a careful consideration of the evidence presented other explanations which take into account the same basic facts are in order. Unless more plausible deductions are offered by those who assume that the same patterns in distribution came about by abnormal and fortuitous means, the condemnation of the original explanation (distribution by fish during periods of confluence) would appear to be without validity. At any rate, a remarkable agreement must be recognized between the information given by glacial geologists and the evidence submitted by malacologists in outlining some of the major events that are generally accepted as explaining present-day drainage systems and geomorphology.

It is clear that benefits are to be derived from the use of facts established by studies of naiades to supplement those in the closely related fields of geology and geomorphology. It is obvious, further, that a large amount of such information in these related fields awaits correlation. I submit that the difficulties encountered are not so much a matter of our inability to accumulate the essential data as of our inability to obtain the proper assistance from those best able to promote such coöperative studies.

It is my firm conviction that methods of investigation similar to those employed for the study of the correlations that exist between mussel distribution in Michigan and the postglacial history as expounded by competent geologists can also be applied to good advantage in more complex regions, such as are found in the southern Appalachians. In view of the complexity of the problems in these areas for geologists and geomorphologists it would seem reasonable that any additional clues which might aid in unraveling the tangle would be welcome. Recognition of the important rôle of zoogeography as an aid in geological and physiographical interpretation is coming more and more to the fore. Outstanding zoologists and geologists recognize this fact. A prominent zoologist (Barbour, 1926) stated: "It is in studying these changes in land form that the zoologist may by analyzing the fauna, aid the geologist and check his conclusions." Schuchert (1935), in his outstanding book on the *Historical Geology of the Antillean-Caribbean Region*, devoted a section to biogeography and showed that a clear-cut agreement is to be found between the fundamental conclusions derived from a consideration of geological history and those established by biogeographical studies of that region.

In accumulating basic facts about our North American fresh-water mussels we are faced with certain practical problems which are not generally appreciated. The information gathered to date is relatively large, thanks to the careful and painstaking work of Rafinesque, Lea, Conrad, H. H. Smith, Simpson, Ortmann, Walker, and others. Much remains to be done, however, particularly in the form of critical river surveys that will give needed data bearing on the ecology and distribution of these animals. Another very serious gap in our essential knowledge is concerned with the life history and distributional relationships between specific groups of mussels and their normal fish hosts. Such studies are hampered by

a lack of interested students able to carry on a research program in a field with so little applied value, as well as by the vast changes which have come about in many of our rivers as a result of silting, the construction of power dams, and pollution from sewage and other sources. Under these circumstances the failure of outstanding geomorphologists to appreciate carefully determined truths does not serve to forward an already difficult cause. The refusal to recognize the facts of distribution available in the literature has prejudiced some individuals not only against the acceptance of the sound work of such good authorities as A. E. Ortmann and B. Walker, but also against the use of mussels as an aid in geomorphic studies. This situation is most unfortunate, for the cause of science suffers when we are not willing to correlate evidence contributed by closely related fields.

In conclusion, a statement made recently by Dr. Maurice C. Hall (1938) seems quite appropriate:

When metaphysics abandoned the authoritarian method it developed into modern science, and when modern science anywhere accepts the authoritarian method it again becomes metaphysics. Unless we can accept the universality of natural law, the working of proportionate cause and effect, and the possibility and necessity of scientists anywhere checking the work of other scientists under different environments in order to rule out personal, local and incidental factors, we might as well abandon science and take up theology or some other subject in which the dicta of authority are accepted as *ex cathedra* statements of fact.

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## SOME HORMONE EFFECTS ON THE VAGINAL MUSCULATURE OF THE RAT \*

NORMAN W. VOGEL

IN HIS attempt to imitate gestational changes in the mouse vagina Schick <sup>1</sup> was able to produce artificially vaginal conditions similar to those of both early and late pregnancy by means of hormone injections and tissue implantations. Using increases in the circumference and weight of the vagina as his index of effect, he found conditions resembling those of *early* pregnancy with progesterone injections and with implantations, subcutaneous or into the vagina, of either corpora lutea or placentas. Testosterone was most successful in producing changes similar to those of *late* pregnancy in the vaginas of virgin mice. The increases in circumference which Schick observed in late pregnancy indicate relaxation of the vaginal musculature, the physiological control of which apparently has not been investigated. In the present series of experiments an attempt was made to determine what, if any, hormonal control is exerted over this muscle. The author is indebted to Dr. Alvalyn E. Woodward, under whose supervision this work was undertaken, for help and guidance. Owing to current conditions the continuance and completion of this work have necessarily been postponed indefinitely.

### METHOD

It was decided that any changes in muscle tension produced by hormone extracts could best be observed by the suspension method, and it was found that they could be recorded on a kymograph by a delicate heart lever. White rats were used because their tissues were of a size more convenient to handle.

The entire vagina was removed from the sacrificed animal; the hair margin was taken as the outer limit and the hard tissue of the

\* Contribution from the Department of Zoology, University of Michigan.

<sup>1</sup> Schick, R. D., "Experimental Simulation of Gestational Changes in the Vagina of the Mouse," *Journ. Morphol.*, 73: 143-175. 1943.

cervix as the inner limit. The vagina was then cut across, into two equal loops of tissue and placed in warm Ringer-Tyrode solution. Effects on both loops, the inner or cervical portion and the outer portion, were recorded individually.

Each tissue "loop" was suspended between a lower hook formed of a fine vertical glass rod and another hook leading upward by a silk thread to a delicate heart lever. The whole suspension was immersed in a bath of Ringer-Tyrode solution at 37° C. and aerated through a capillary tube. Just sufficient fluid was used in the shell vial to immerse the tissue completely. Care was taken not to place undue tension on the tissue loop while recording any muscular contraction or relaxation. To accomplish this a writing point was carefully adjusted to trace upon a slow-moving lightly smoked kymograph drum.

Dosages of five international units of pitocin (Parke, Davis and Co.), or thirty rat units of theelin (Parke, Davis and Co., Aqueous Suspension), were added in each case to the 25 c.c. of saline bath solution. Placental extracts, which were also used, were made from fresh rat or hog placentas by cutting up the tissue and allowing it to stand in Ringer-Tyrode solution at least twelve hours under refrigeration. The filtered extract was of undetermined but relatively high concentration.

The effects of the various hormones and extracts to be tested were determined by placing them in the Ringer bath after the vaginal loop had been allowed to make a control record for about thirty minutes, during which time any normal relaxation would have taken place. From thirty minutes to one hour was allowed for any possible response to each dose.

Most of the virgin vaginas were taken in estrous stage, as determined by the vaginal smear technique. All pregnant vaginas were within one or two days of parturition.

#### RESULTS

Neither pitocin nor theelin alone had any apparent effect on the outer vaginal portion. However, a mild increase in tonus resulted with theelin in the inner or cervical portion of diestrous and estrous vaginas of virgin animals and in preparations made late in pregnancy. In some cases the injection of pitocin after theelin produced an additional increase in tonus, and in at least one or two a relatively

strong uterine-like contraction occurred immediately upon administration of this pituitary extract.

The most promising response, however, in respect to the phenomena which were of interest, here resulted from the application of fresh placental extract (rat). A pronounced relaxation of both tissue loops of the preparations taken late in pregnancy occurred in a majority of the cases upon the addition of this material to the bath in unknown but relatively high concentrations. There may be some species-specific reaction here, for the addition of hog placental extract in two experiments did not duplicate and confirm these results, but, on the contrary, apparently produced contraction. However, as yet an insufficient number of experiments have been performed to make positive statements concerning this specificity.

#### SUMMARY

1. Pitocin alone had no effect on the tonus of the vaginal muscle of the white rat.

2. Theelin produced a slight tonic contraction in the inner or cervical half of vaginas from diestrous, estrous, and pregnant rats.

3. Pitocin administered after theelin stimulated the vaginal muscle to still greater contraction.

4. A saline extract of fresh rat placentas brought about pronounced relaxation of both inner and outer portions of vaginas taken from rats late in pregnancy.



## MORE DATA ON DEPRESSION INDIVIDUALITY IN DOUGLAS LAKE, MICHIGAN \*

PAUL S. WELCH

**I**N 1928 the writer published a paper dealing with certain limnological features of Douglas Lake, Michigan, in which depression individuality was definitely reported for the first time. Later (Welch and Eggleton, 1932, 1935) more data were added. In the meantime this phenomenon was found in certain multidepression lakes by other investigators. The peculiarly favorable structure of the Douglas Lake basin for this kind of investigation, the recognized importance of limnological researches extended over many seasons, and the challenge of associated problems led to the accumulation of still further data, a certain portion of which is presented here. The previously published data covered eighteen summers. Records for eight other summers are now added, making a total of twenty-six seasons. In no other lake has depression behavior been followed for so long a period. Since this series now seems adequate to exhibit the usual variations and other features of depression individuality in Douglas Lake, the writer expects to discontinue records of this sort except when necessity demands them in connection with other research projects.

The records given in the tables (Tables I-II) attached to this paper are selected from a larger number made during the progress of the work. For the most part the organization of the tables follows that of previous papers in order that comparisons may be facilitated. The field and laboratory methods were essentially those employed in the earlier work except that during recent seasons extensive use was made of a modern, sensitive electrical-resistance thermometer outfit constructed by the Foxboro Company. In all records thermocline limits were determined by the application of Birge's rule.

\* Contribution from the Biological Station and the Department of Zoology, University of Michigan. This work was facilitated by a grant from the University of Michigan Faculty Research Fund.

The results from these last eight seasons, when compared with those of the preceding eighteen, are largely confirmatory. Well-defined individuality in the major depressions is consistently exhibited. Additions to the many details of depression performance have been made, but are of such a nature that they need not be listed here.

During the summers of 1938-42 many vertical temperature records were made from the various depressions on corresponding dates and at very close depth intervals, sometimes as small as 0.1 meter. One purpose of these series was to work out the detailed structure of the thermocline and to discover whether depression individuality extends also to the internal distribution of temperature. These voluminous records cannot be published here, but the principal result may be stated in very brief form. It was found that, when the successive values of fall in temperature from one level to the next lowest are plotted, the differences in internal structure of the thermoclines in the several depressions on the same or similar dates are made visible and easy to compare. From such graphs it is clear that, in addition to features stressed in earlier papers, depression individuality extends also to the internal structure of the thermocline.

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TABLE I

## SUMMARY OF THERMAL STRATIFICATION IN DIFFERENT DEPRESSIONS

| Date                                                  | Depth<br>(meters) | Surface<br>temp.<br>(° C.) | Bottom<br>temp.<br>(° C.) | Thermocline              |                              |
|-------------------------------------------------------|-------------------|----------------------------|---------------------------|--------------------------|------------------------------|
|                                                       |                   |                            |                           | Depth limits<br>(meters) | Temperature limits<br>(° C.) |
| South Fish-Tail Depression (maximum depth, 24 meters) |                   |                            |                           |                          |                              |
| 1934                                                  |                   |                            |                           |                          |                              |
| July 4                                                | 23                | 21.8                       | 10.5                      | 11-14<br>16-17           | 20.6-13.6<br>13.0-11.7       |
| July 25                                               | 23                | 25.0                       | 10.5                      | 12-16                    | 20.2-12.8                    |
| Aug. 10                                               | 20                | 24.2                       | 10.1                      | 11-15                    | 20.8-12.2                    |
| 1935                                                  |                   |                            |                           |                          |                              |
| July 24                                               | 20                | 26.4                       | 8.2                       | 8-16                     | 21.6-9.6                     |
| Aug. 14                                               | 22                | 24.3                       | 8.2                       | 10-16                    | 20.8-9.6                     |
| 1936                                                  |                   |                            |                           |                          |                              |
| July 11                                               | 20                | 29.1                       | 9.2                       | 4-7<br>12-16             | 25.0-20.2<br>18.2-11.8       |
| Aug. 7                                                | 20                | 22.0                       | 9.8                       | 12-17                    | 20.4-11.4                    |
| 1937                                                  |                   |                            |                           |                          |                              |
| July 12                                               | 23                | 27.0                       | 9.6                       | 8-9<br>11-15             | 19.4-18.1<br>17.2-10.5       |
| July 23                                               | 22                | 23.9                       | 9.6                       | 9-11<br>13-14            | 21.8-18.6<br>17.2-12.8       |
| July 28                                               | 22                | 19.8                       | 9.6                       | 15-17                    | 18.8-11.6                    |
| Aug. 11                                               | 22                | 25.2                       | 9.3                       | 13-17                    | 19.5-11.0                    |
| 1938                                                  |                   |                            |                           |                          |                              |
| July 6                                                | 22                | 23.3                       | 8.7                       | 1-4<br>11-13             | 23.0-19.0<br>15.3-12.6       |
| July 22                                               | 21                | 22.0                       | 10.0                      | 10-16                    | 20.3-12.0                    |
| July 29                                               | 21                | 22.1                       | 10.4                      | 11-15                    | 20.7-13.5                    |
| Aug. 26                                               | 23                | 20.4                       | 9.2                       | 12-15                    | 19.7-11.4                    |
| 1939                                                  |                   |                            |                           |                          |                              |
| June 26                                               | 22                | 21.5                       | 7.4                       | 12-16                    | 17.2-9.7                     |
| July 5                                                | 21                | 22.3                       | 7.5                       | 9-17                     | 20.2-8.3                     |
| July 11                                               | 23                | 23.5                       | 7.5                       | 10-17.7                  | 20.1-8.0                     |
| July 20                                               | 21                | 22.3                       | 7.6                       | 12-16.6                  | 19.7-8.8                     |
| July 28                                               | 20                | 25.5                       | 7.9                       | 4-6<br>12-16             | 23.5-20.6<br>18.1-7.5        |
| Aug. 4                                                | 21                | 23.4                       | 7.9                       | 12-16                    | 19.5-9.3                     |
| Aug. 14                                               | 21                | 23.2                       | 7.8                       | 11.6-16                  | 20.4-9.2                     |
| 1940                                                  |                   |                            |                           |                          |                              |
| June 26                                               | 22                | 16.1                       | 6.9                       | 14.5-17                  | 14.7-8.0                     |
| July 3                                                | 20                | 18.4                       | 7.1                       | 14-17                    | 15.2-7.9                     |
| July 17                                               | 20                | 19.0                       | 7.1                       | 9-10<br>14-17            | 17.7-16.1<br>14.5-8.3        |



TABLE I (Continued)

| Date                                              | Depth<br>(meters) | Surface<br>temp.<br>(° C.) | Bottom<br>temp.<br>(° C.) | Thermocline              |                              |
|---------------------------------------------------|-------------------|----------------------------|---------------------------|--------------------------|------------------------------|
|                                                   |                   |                            |                           | Depth limits<br>(meters) | Temperature limits<br>(° C.) |
| South Fish-Tail Depression (Concluded)            |                   |                            |                           |                          |                              |
| July 24                                           | 21                | 25.3                       | 7.3                       | 14-18                    | 14.4-7.4                     |
| Aug. 15                                           | 21                | 23.2                       | 7.3                       | 8-10<br>12-16.6          | 20.2-17.8<br>16.0-9.3        |
| 1941                                              |                   |                            |                           |                          |                              |
| July 9                                            | 23                | 22.7                       | 6.2                       | 10-17                    | 20.5-7.0                     |
| July 21                                           | 23                | 20.2                       | 6.2                       | 13-16                    | 18.4-8.0                     |
| July 23                                           | 22                | 22.0                       | 6.2                       | 12-16                    | 18.6-8.0                     |
| Aug. 9                                            | 20                | 25.0                       | 6.5                       | 12-18                    | 19.0-8.0                     |
| 1942                                              |                   |                            |                           |                          |                              |
| July 8                                            | 22                | 19.2                       | 7.0                       | 11-16                    | 17.5-9.0                     |
| July 31                                           | 23                | 23.3                       | 7.2                       | 10-16                    | 21.2-9.4                     |
| Aug. 12                                           | 20                | 21.0                       | 7.2                       | 13-17                    | 19.9-9.9                     |
| 1943                                              |                   |                            |                           |                          |                              |
| July 7                                            | 23                | 22.0                       | 8.3                       | 12-15                    | 18.3-10.0                    |
| July 23                                           | 21                | 22.5                       | 9.1                       | 11-15                    | 20.3-10.5                    |
| Aug. 18                                           | 21                | 20.0                       | 9.0                       | 13-16                    | 19.4-10.0                    |
| Sedge Point Depression (maximum depth, 24 meters) |                   |                            |                           |                          |                              |
| 1934                                              |                   |                            |                           |                          |                              |
| July 3                                            | 22                | 22.0                       | 11.4                      | 11-12<br>16-18           | 20.8-19.3<br>17.6-12.3       |
| Aug. 6                                            | 23                | 22.2                       | 11.6                      | 15-18                    | 20.7-13.6                    |
| 1937                                              |                   |                            |                           |                          |                              |
| Aug. 9                                            | 22                | 24.7                       | 13.1                      | 14-17                    | 19.2-14.6                    |
| 1938                                              |                   |                            |                           |                          |                              |
| Aug. 25                                           | 25                | 21.3                       | 12.3                      | 14-16                    | 19.9-13.7                    |
| 1939                                              |                   |                            |                           |                          |                              |
| June 29                                           | 22                | 23.5                       | 12.5                      | 5-6<br>19-21.5           | 20.9-19.7<br>16.9-12.5       |
| July 6                                            | 22                | 29.1                       | 11.9                      | 8-9<br>17-20             | 20.8-19.6<br>16.8-12.9       |
| July 17                                           | 20                | 21.4                       | 13.7                      | 13.5-18.4                | 18.4-12.5                    |
| Aug. 8                                            | 22                | 23.2                       | 13.0                      | 15.4-17                  | 18.8-15.0                    |
| 1940                                              |                   |                            |                           |                          |                              |
| July 9                                            | 21                | 22.4                       | 12.1                      | 4-5<br>17-18.2           | 20.5-19.2<br>15.5-13.1       |
| July 26                                           | 21                | 24.6                       | 12.8                      | 4-9<br>17-18             | 23.7-18.1<br>15.2-14.2       |
| Aug. 15                                           | 22                | 22.7                       | 12.7                      | 8-10                     | 20.6-17.5                    |
| 1941                                              |                   |                            |                           |                          |                              |
| Aug. 2                                            | 20                | 25.6                       | 12.5                      | 16-19                    | 18.2-12.8                    |

TABLE I (Continued)

| Date                                                  | Depth<br>(meters) | Surface<br>temp.<br>(° C.) | Bottom<br>temp.<br>(° C.) | Thermocline              |                              |
|-------------------------------------------------------|-------------------|----------------------------|---------------------------|--------------------------|------------------------------|
|                                                       |                   |                            |                           | Depth limits<br>(meters) | Temperature limits<br>(° C.) |
| Grapevine Point Depression (maximum depth, 25 meters) |                   |                            |                           |                          |                              |
| 1934                                                  |                   |                            |                           |                          |                              |
| July 3                                                | 23                | 21.4                       | 11.6                      | 14-17                    | 18.4-12.4                    |
| 1937                                                  |                   |                            |                           |                          |                              |
| Aug. 9                                                | 22                | 22.0                       | 12.8                      | 14-17                    | 18.6-13.9                    |
| 1939                                                  |                   |                            |                           |                          |                              |
| June 27                                               | 24                | 21.4                       | 17.3                      | 5-6                      | 21.1-19.5                    |
| July 6                                                | 24                | 24.7                       | 16.7                      | No stratification        |                              |
| July 18                                               | 24                | 22.0                       | 16.7                      | 14-15                    | 19.7-18.3                    |
| Aug. 7                                                | 24                | 23.5                       | 16.6                      | No stratification        |                              |
| Aug. 16                                               | 24                | 24.4                       | 16.5                      | 14-15                    | 20.3-19.0                    |
| 1940                                                  |                   |                            |                           |                          |                              |
| July 4                                                | 23                | 18.7                       | 10.2                      | 3-4                      | 17.9-16.8                    |
|                                                       |                   |                            |                           | 21-22                    | 14.7-10.3                    |
| July 23                                               | 23                | 26.1                       | 14.3                      | 0-3                      | 26.1-21.9                    |
|                                                       |                   |                            |                           | 5-9                      | 20.7-17.1                    |
| Aug. 13                                               | 22                | 24.9                       | 14.5                      | 8-10                     | 21.3-17.1                    |
| 1941                                                  |                   |                            |                           |                          |                              |
| July 29                                               | 22                | 27.1                       | 11.9                      | 17-20                    | 16.2-12.1                    |
| Stony Point Depression (maximum depth, 18 meters)     |                   |                            |                           |                          |                              |
| 1934                                                  |                   |                            |                           |                          |                              |
| July 5                                                | 19                | 22.5                       | 13.6                      | 13-17                    | 19.9-13.6                    |
| Aug. 10                                               | 19                | 24.0                       | 14.9                      | 13-15                    | 20.6-16.0                    |
| 1937                                                  |                   |                            |                           |                          |                              |
| Aug. 9                                                | 17                | 24.0                       | 18.9                      | No stratification        |                              |
| 1939                                                  |                   |                            |                           |                          |                              |
| July 19                                               | 18                | 21.7                       | 17.2                      | 16-16.5                  | 19.6-17.7                    |
| 1940                                                  |                   |                            |                           |                          |                              |
| July 23                                               | 16                | 26.6                       | 14.0                      | 1-3                      | 25.7-21.5                    |
|                                                       |                   |                            |                           | 6-7                      | 19.9-18.9                    |
| Aug. 13                                               | 18                | 25.8                       | 15.9                      | 7-10                     | 21.2-17.3                    |
| 1941                                                  |                   |                            |                           |                          |                              |
| Aug. 2                                                | 15                | 25.2                       | 19.2                      | No stratification        |                              |
| Roberts Point Depression (maximum depth, 22 meters)   |                   |                            |                           |                          |                              |
| 1934                                                  |                   |                            |                           |                          |                              |
| July 5                                                | 21                | 21.9                       | 11.3                      | 11-16                    | 20.4-12.4                    |

TABLE I (Concluded)

| Date                                               | Depth<br>(meters) | Surface<br>temp.<br>(° C.) | Bottom<br>temp.<br>(° C.) | Thermocline              |                              |
|----------------------------------------------------|-------------------|----------------------------|---------------------------|--------------------------|------------------------------|
|                                                    |                   |                            |                           | Depth limits<br>(meters) | Temperature limits<br>(° C.) |
| Roberts Point Depression (Concluded)               |                   |                            |                           |                          |                              |
| 1937                                               |                   |                            |                           |                          |                              |
| Aug. 9                                             | 18.5              | 24.0                       | 11.6                      | 12-17                    | 18.6-12.0                    |
| 1938                                               |                   |                            |                           |                          |                              |
| Aug. 25                                            | 22                | 21.0                       | 12.0                      | 12-13.7                  | 19.6-13.7                    |
| 1939                                               |                   |                            |                           |                          |                              |
| June 29                                            | 19                | 24.4                       | 11.3                      | 2-4                      | 24.1-20.5                    |
|                                                    |                   |                            |                           | 15-18.5                  | 15.7-11.6                    |
| July 17                                            | 22                | 21.6                       | 11.2                      | 13-16                    | 19.0-18.4                    |
| Aug. 10                                            | 20                | 23.5                       | 12.3                      | 11.4-17                  | 21.1-13.3                    |
| 1940                                               |                   |                            |                           |                          |                              |
| July 9                                             | 19                | 23.7                       | 10.2                      | 3-4                      | 20.8-18.1                    |
|                                                    |                   |                            |                           | 5-6                      | 18.5-17.5                    |
|                                                    |                   |                            |                           | 15-18                    | 15.4-10.3                    |
| Aug. 1                                             | 20                | 22.6                       | 11.6                      | 7-10                     | 22.1-16.6                    |
| Aug. 17                                            | 20                | 25.3                       | 13.4                      | 9-12                     | 22.5-17.6                    |
| 1941                                               |                   |                            |                           |                          |                              |
| July 29                                            | 19                | 27.3                       | 8.8                       | 11-17                    | 18.9-9.7                     |
| Fairy Island Depression (maximum depth, 28 meters) |                   |                            |                           |                          |                              |
| 1934                                               |                   |                            |                           |                          |                              |
| July 2                                             | 26                | 21.4                       | 12.2                      | 13-15                    | 17.4-13.8                    |
| Aug. 6                                             | 25                | 22.2                       | 11.5                      | 13-17                    | 19.8-12.8                    |
| 1937                                               |                   |                            |                           |                          |                              |
| Aug. 11                                            | 24                | 24.6                       | 11.5                      | 13-16                    | 18.5-12.5                    |
| 1938                                               |                   |                            |                           |                          |                              |
| Aug. 25                                            | 27                | 21.8                       | 11.4                      | 12-15                    | 19.8-12.6                    |
| 1939                                               |                   |                            |                           |                          |                              |
| July 4                                             | 24                | 22.0                       | 10.7                      | 7-8                      | 21.1-20.1                    |
| July 18                                            | 24                | 21.1                       | 10.6                      | 12-16                    | 19.3-13.5                    |
| 1940                                               |                   |                            |                           |                          |                              |
| July 13                                            | 25                | 20.7                       | 9.4                       | 4-6                      | 20.3-17.9                    |
|                                                    |                   |                            |                           | 15.6-18.4                | 14.8-10.6                    |
| Aug. 1                                             | 26                | 23.1                       | 10.2                      | 7-9                      | 20.6-17.5                    |
|                                                    |                   |                            |                           | 16-17                    | 13.7-12.7                    |
| Aug. 17                                            | 26                | 25.0                       | 11.6                      | 8-18                     | 23.1-17.1                    |
| 1941                                               |                   |                            |                           |                          |                              |
| July 29                                            | 26                | 26.5                       | 8.3                       | 13-18                    | 18.2-10.4                    |

TABLE II

## SUMMARY OF CHEMICAL ANALYSES

Abbreviations: t. s., thermal stratification; t. gr., temperature gradient; c. s., chemical stratification; c. gr., chemical gradient (gradual quantitative change in chemical features from surface to bottom)

| Date                                 | Temperature conditions | Chemical conditions | Dissolved oxygen         |                       |                    | Free CO <sub>2</sub>      |                    | Methyl-orange alkalinity p.p.m. | pH                 |                    |
|--------------------------------------|------------------------|---------------------|--------------------------|-----------------------|--------------------|---------------------------|--------------------|---------------------------------|--------------------|--------------------|
|                                      |                        |                     | Surface and bottom cc./l | Thermocline cc./l     | Oxygenless zone m. | Surface and bottom p.p.m. | Thermocline p.p.m. |                                 | Surface and bottom | Thermocline        |
| South Fish-Tail Depression           |                        |                     |                          |                       |                    |                           |                    |                                 |                    |                    |
| 1934<br>July 4<br>July 25<br>Aug. 10 | t. s.                  | c. s.               | 5.21-0.0                 | 4.2-2.56<br>1.68-0.73 | 19-23              | 0.0-7.0                   | 0.0-1.0<br>3.0-4.0 | 108-124                         | 8.2-6.9            | 8.2-7.7<br>7.3-7.2 |
|                                      | t. s.                  | c. s.               | 3.95-0.0                 | 1.56-0.0              | 16-23              | 0.0-7.0                   | 1.0-5.0            | 120-138                         | 8.2-6.9            | 7.8-7.0            |
|                                      | t. s.                  | c. s.               | 4.99-0.0                 | 4.72-0.42             | 17-23              | 0.0-8.5                   | 0.0-6.0            | 124-134                         | 8.2-7.0            | 8.0-7.1            |
| 1935<br>July 3<br>July 24<br>Aug. 14 | t. s.                  | c. s.               | 5.57-0.03                | 3.57-0.49             | 20-23              | 0.0-3.0                   | 1.5-2.8            | 124-126                         | 8.2-7.0            | 7.7-7.1            |
|                                      | t. s.                  | c. s.               | 5.38-0.0                 | 5.2-0.63              | 18-23              | 0.0-4.0                   | 0.0-2.5            | 130-142                         | 8.4-7.0            | 8.0-7.4            |
|                                      | t. s.                  | c. s.               | 5.57-0.0                 | 4.63-0.03             | 18-23              | 0.0-5.0                   | 0.0-3.0            | 124-130                         | 8.2-6.9            | 8.0-7.0            |
| 1936<br>July 8<br>Aug. 7             | t. s.                  | c. s.               | 5.11-0.0                 | 4.4-0.82              | 21-23              | 0.0-6.0                   | 1.0-4.0            | 102-130                         | 8.0-7.0            | 7.8-7.1            |
|                                      | t. s.                  | c. s.               | 4.94-0.0                 | 3.78-0.0              | 17-23              | 0.0-6.0                   | 0.0-5.0            | 126-132                         | 8.0-7.0            | 7.9-7.0            |
| 1937<br>July 7<br>July 23            | t. s.                  | c. s.               | 4.95-0.0                 | 3.2-1.7               | 19-23              | 0.0-5.0                   | 1.0-3.5            | 125-136                         | 8.0-7.1            | 7.8-7.2            |
|                                      | t. s.                  | c. s.               | 5.4-0.0                  | 4.4-2.8               | 18-23              | 0.0-5.0                   | 0.0-1.5            | 116-139                         | 8.1-6.9            | 8.0-7.5            |
|                                      |                        |                     |                          | 1.4-1.1               |                    |                           | 2.0-3.0            | 0.0-3.0                         |                    | 7.3-7.2            |
| July 28<br>Aug. 11                   | t. s.                  | c. s.               | 5.5-0.0                  | 4.6-0.0               | 17-23              | 0.0-4.0                   | 0.0-3.0            | 130-135                         | 8.0-7.0            | 8.0-7.1            |
|                                      | t. s.                  | c. s.               | 5.6-0.0                  | 3.2-0.0               | 17-23              | 0.0-10.0                  | 1.5-10.0           | 130-142                         | 8.2-7.0            | 7.7-7.2            |
| 1938<br>July 6                       | t. s.                  | c. s.               | 5.34-0.0                 | 5.34-5.34<br>3.0-2.8  | 18-23              | 0.0-5.0                   | 0.0-0.0<br>1.0-2.0 | 120-129                         | 8.0-7.0            | 8.0-8.0<br>7.5-7.4 |

TABLE II (Continued)

| Date                                   | Temperature conditions | Chemical conditions | Dissolved oxygen         |                   |                     | Free CO <sub>2</sub>      |                    | Methyl-orange alkalinity p.p.m. | pH                 |             |  |
|----------------------------------------|------------------------|---------------------|--------------------------|-------------------|---------------------|---------------------------|--------------------|---------------------------------|--------------------|-------------|--|
|                                        |                        |                     | Surface and bottom cc./l | Thermocline cc./l | Oxygen-less zone m. | Surface and bottom p.p.m. | Thermocline p.p.m. |                                 | Surface and bottom | Thermocline |  |
| South Fish-Tail Depression (Concluded) |                        |                     |                          |                   |                     |                           |                    |                                 |                    |             |  |
| July 22                                | t. s.                  | c. s.               | 5.23-0.0                 | 4.9 -0.23         | 18-23               | 0.0-5.0                   | 0.5-3.0            | 116-134                         | 8.2-7.0            | 7.8-7.1     |  |
| July 29                                | t. s.                  | c. s.               | 5.26-0.0                 | 3.4 -0.5          | 17-23               | 0.0-5.0                   | 1.0-3.5            | 117-120                         | 8.0-7.3            | 7.6-7.3     |  |
| 1939                                   |                        |                     |                          |                   |                     |                           |                    |                                 |                    |             |  |
| July 5                                 | t. s.                  | c. s.               | 5.67-0.0                 | 5.4 -0.06         | 18-23               | 0.0-4.0                   | 0.0-3.0            | 107-114                         | 8.3-7.0            | 7.9-7.1     |  |
| July 11                                | t. s.                  | c. s.               | 5.13-0.13                | 4.3 -0.47         | Absent              | 0.0-15.0                  | 0.0-6.0            | 117-130                         | 8.3-7.0            | 7.9-7.4     |  |
| July 20                                | t. s.                  | c. s.               | 5.7 -0.0                 | 4.6 -0.1          | 21-23               | 0.0-7.0                   | 0.0-7.0            | 122-132                         | 8.2-6.9            | 7.8-6.9     |  |
| July 28                                | t. s.                  | c. s.               | 6.3 -0.0                 | 3.2 -0.24         | 18-23               | 0.0-3.0                   | 0.5-3.0            | 116-132                         | 8.3-7.0            | 7.6-7.1     |  |
| Aug. 4                                 | t. s.                  | c. s.               | 3.8 -0.0                 | 2.0 -0.1          | 17-23               | 0.0-14.0                  | 1.0-8.0            | 115-141                         | 8.2-6.9            | 7.5-7.0     |  |
| Aug. 14                                | t. s.                  | c. s.               | 5.5 -0.0                 | 2.9 -0.0          | 13.7-23             | 0.0-9.0                   | 0.5-7.0            | 121-140                         | 8.2-6.9            | 7.7-6.9     |  |
| 1940                                   |                        |                     |                          |                   |                     |                           |                    |                                 |                    |             |  |
| June 26                                | t. s.                  | c. s.               | 6.1 -0.07                | 5.37-3.21         | Absent              | 0.0-2.0                   | 0.0-2.0            | 122-133                         | 8.0-6.9            | 8.0-7.2     |  |
| July 3                                 | t. s.                  | c. s.               | 5.92-0.0                 | 5.4 -0.2          | 20-23               | 0.0-10.0                  | 0.0-10.0           | 119-133                         | 8.2-7.0            | 8.0-7.0     |  |
| July 17                                | t. s.                  | c. s.               | 5.72-0.0                 | 5.6 -5.1          | 18-23               | 0.0-12.0                  | 0.0-0.0            | 120-131                         | 8.2-6.9            | 8.0-8.0     |  |
| July 24                                | t. s.                  | c. s.               | 5.23-5.0                 | 5.3 -0.03         | 19-23               | 0.0-12.0                  | 0.0-0.0            | 118-131                         | 8.2-7.0            | 7.6-7.0     |  |
| Aug. 15                                | t. s.                  | c. s.               | 5.43-0.0                 | 5.2 -5.7          | 18-23               | 0.0-14.0                  | 6.0-12.0           | 111-134                         | 8.3-7.1            | 8.2-8.2     |  |
|                                        |                        |                     |                          | 2.15-0.06         |                     |                           | 0.0-2.0            |                                 | 8.0-7.6            | 7.2-7.0     |  |
|                                        |                        |                     |                          | 1.83-0.03         |                     |                           | 3.0-10.0           |                                 | 7.5-7.1            | 7.5-7.1     |  |
| 1941                                   |                        |                     |                          |                   |                     |                           |                    |                                 |                    |             |  |
| July 9                                 | t. s.                  | c. s.               | 5.43-0.0                 | 4.54-0.34         | 20-23               | 0.0-10.0                  | 0.0-7.0            | 120-132                         | 8.4-7.0            | 8.2-7.0     |  |
| July 23                                | t. s.                  | c. s.               | 5.63-0.0                 | 4.63-0.6          | 19-23               | 0.0-12.0                  | 0.0-7.0            | 121-131                         | 8.4-7.0            | 7.9-7.1     |  |
| Aug. 9                                 | t. s.                  | c. s.               | 5.32-0.0                 | 2.72-0.05         | 19-23               | 0.0-12.0                  | 0.0-10.0           | 123-138                         | 8.3-6.9            | 7.6-7.1     |  |
| 1942                                   |                        |                     |                          |                   |                     |                           |                    |                                 |                    |             |  |
| July 8                                 | t. s.                  | c. s.               | 5.51-0.0                 | 5.02-1.04         | 21-23               | 0.0-10.0                  | 0.0-7.0            | 118-125                         | 8.2-7.1            | 7.9-7.1     |  |
| July 31                                | t. s.                  | c. s.               | 5.37-0.0                 | 3.27-0.2          | 19-23               | 0.0-9.0                   | 0.0-8.0            | 115-127                         | 8.4-7.0            | 8.0-7.1     |  |
| 1943                                   |                        |                     |                          |                   |                     |                           |                    |                                 |                    |             |  |
| July 7                                 | t. s.                  | c. s.               | 5.23-0.0                 | 3.9 -2.72         | 20-23               | 0.0-10.0                  | 2.0-5.0            | 116-130                         | 8.2-7.2            | 7.8-7.3     |  |
| July 23                                | t. s.                  | c. s.               | 5.3 -0.0                 | 4.29-1.4          | 20-23               | 0.0-7.0                   | 2.0-7.0            | 122-135                         | 8.2-7.0            | 7.5-7.0     |  |
| Aug. 18                                | t. s.                  | c. s.               | 5.71-0.0                 | 4.88-0.69         | 17-23               | 0.0-7.0                   | 0.0-5.0            | 124-124                         | 8.2-7.0            | 7.8-7.2     |  |

TABLE II (Continued)

| Date                       | Temperature conditions | Chemical conditions | Dissolved oxygen         |                   |                    | Free CO <sub>2</sub>      |                    | Methyl-orange alkalinity p.p.m. | pH                 |             |
|----------------------------|------------------------|---------------------|--------------------------|-------------------|--------------------|---------------------------|--------------------|---------------------------------|--------------------|-------------|
|                            |                        |                     | Surface and bottom cc./l | Thermocline cc./l | Oxygenless zone m. | Surface and bottom p.p.m. | Thermocline p.p.m. |                                 | Surface and bottom | Thermocline |
| Sedge Point Depression     |                        |                     |                          |                   |                    |                           |                    |                                 |                    |             |
| 1934<br>July 3             | t. s.                  | c. s.               | 4.48-0.0                 | 2.42-0.73         | 19-25              | 0.0-5.0                   | 1.0-2.0            | 110-124                         | 8.2-6.8            | 7.4-7.0     |
| Aug. 6                     | t. s.                  | c. s.               | 4.72-0.0                 | 0.35-0.0          | 17-25              | 0.0-7.0                   | 1.0-6.0            | 128-134                         | 8.2-7.0            | 7.6-7.1     |
| 1937<br>Aug. 9             | t. s.                  | c. s.               | 5.5-0.0                  | 1.5-0.0           | 17-25              | 0.0-13.0                  | 4.0-9.0            | 129-142                         | 8.2-7.1            | 7.4-7.2     |
| 1939<br>June 29            | t. s.                  | c. s.               | 6.2-0.0                  | 3.3-0.1           | 22-25              | 0.0-6.0                   | 2.0-6.0            | 116-129                         | 8.2-7.0            | 7.4-7.1     |
| July 6                     | t. s.                  | c. s.               | 5.6-0.0                  | 5.0-4.6           | 23-25              | 0.0-5.0                   | 0.0-0.0            | 123-132                         | 8.2-7.0            | 8.2-8.0     |
| July 17                    | t. s.                  | c. s.               | 5.4-0.0                  | 2.6-0.75          | 22-25              | 0.0-5.0                   | 2.0-5.0            | 116-122                         | 8.2-7.3            | 7.4-7.2     |
| Aug. 8                     | t. s.                  | c. s.               | 5.1-0.0                  | 4.8-0.61          | 16.7-25            | 0.0-7.0                   | 0.0-4.5            | 121-137                         | 8.2-7.1            | 8.1-7.3     |
| 1940<br>July 9             | t. s.                  | c. s.               | 5.48-0.0                 | 5.4-5.8           | 21-25              | 0.0-2.0                   | 0.0-0.0            | 112-124                         | 8.2-7.2            | 8.2-8.2     |
| July 26                    | t. s.                  | c. s.               | 5.3-0.0                  | 3.8-3.58          | 21-25              | 0.0-4.0                   | 0.5-0.5            | 120-132                         | 8.2-7.2            | 7.7-7.6     |
| Aug. 15                    | t. s.                  | c. s.               | 5.37-0.0                 | 5.5-4.0           | 17-25              | 0.0-7.0                   | 0.0-0.0            | 115-133                         | 8.3-7.1            | 8.3-8.0     |
| 1941<br>Aug. 2             | t. s.                  | c. s.               | 5.22-0.0                 | 2.21-1.87         | 17-25              | 0.0-7.0                   | 2.0-2.0            | 114-136                         | 8.3-7.1            | 7.4-7.3     |
|                            |                        |                     |                          | 3.0-2.1           |                    |                           | 0.0-1.0            |                                 |                    | 8.0-7.7     |
|                            |                        |                     |                          | 0.2-0.0           | 19-25              | 0.0-10.0                  | 7.0-10.0           |                                 | 8.4-7.1            | 7.2-7.1     |
| Grapevine Point Depression |                        |                     |                          |                   |                    |                           |                    |                                 |                    |             |
| 1934<br>July 3             | t. s.                  | c. s.               | 5.28-0.0                 | 2.49-0.29         | 20-25              | 0.0-9.0                   | 3.0-6.0            | 102-136                         | 8.2-6.9            | 7.5-7.0     |
| 1937<br>Aug. 9             | t. s.                  | c. s.               | 6.8-0.0                  | 2.18-0.03         | 18-25              | 0.0-14.0                  | 3.0-8.0            | 114-136                         | 8.2-7.2            | 7.5-7.2     |
| 1939<br>June 29            | t. s.                  | c. s.               | 5.6-2.2                  | 5.6-5.5           | 0                  | 0.0-4.0                   | 0.0-0.0            | 117-128                         | 8.2-7.2            | 8.2-8.2     |
| July 6                     | t. gr.                 | c. gr.              | 5.3-0.9                  | No strat.         | 0                  | 0.0-3.0                   | .....              | 126-126                         | 8.2-7.2            | .....       |

TABLE II (Continued)

| Date                                   | Temperature conditions | Chemical conditions | Dissolved oxygen         |                   |                    | Free CO <sub>2</sub>      |                    | Methyl-orange alkalinity p.p.m. | pH                 |             |  |
|----------------------------------------|------------------------|---------------------|--------------------------|-------------------|--------------------|---------------------------|--------------------|---------------------------------|--------------------|-------------|--|
|                                        |                        |                     | Surface and bottom cc./l | Thermocline cc./l | Oxygenless zone m. | Surface and bottom p.p.m. | Thermocline p.p.m. |                                 | Surface and bottom | Thermocline |  |
| Grapevine Point Depression (Concluded) |                        |                     |                          |                   |                    |                           |                    |                                 |                    |             |  |
| July 18                                | t. s.                  | c. s.               | 5.7 -0.0                 | 3.2 -1.5          | 23-25              | 0.0-7.0                   | 2.0-3.0            | 116-128                         | 8.2-7.1            | 7.4-7.3     |  |
| Aug. 7                                 | t. gr.                 | c. gr.              | 5.03-0.0                 | No strat.         | 22-25              | 0.0-6.0                   | .....              | 117-134                         | 8.2-7.1            | .....       |  |
| Aug. 16                                | t. s.                  | c. s.               | 5.28-0.0                 | 2.23-1.5          | 16-25              | 0.0-9.0                   | 2.0-3.0            | 128-136                         | 8.2-7.2            | 7.6-7.4     |  |
| 1940                                   |                        |                     |                          |                   |                    |                           |                    |                                 |                    |             |  |
| July 4                                 | t. s.                  | c. s.               | 5.0 -0.65                | 5.0 -5.0          | 0                  | 0.0-0.0                   | 0.0-0.0            | 117-125                         | 8.2-7.2            | 8.2-8.1     |  |
|                                        |                        |                     |                          | 4.53-4.53         |                    |                           | 0.0-0.0            |                                 |                    | 7.8-7.7     |  |
| July 23                                | t. s.                  | c. gr.              | 5.0 -1.0                 | 5.0 -5.2          | 0                  | 0.0-6.0                   | 0.0-0.0            | 114-131                         | 8.2-7.2            | 8.2-8.2     |  |
|                                        |                        |                     |                          | 5.5 -4.0          |                    |                           | 0.0-0.0            |                                 |                    | 8.2-7.8     |  |
| Aug. 13                                | t. s.                  | c. s.               | 5.85-0.0                 | 4.9 -2.8          | 18-25              | 0.0-10.0                  | 0.0-2.0            | 120-132                         | 8.2-7.1            | 7.9-7.7     |  |
| 1941                                   |                        |                     |                          |                   |                    |                           |                    |                                 |                    |             |  |
| July 29                                | t. s.                  | c. s.               | 5.42-0.13                | 0.4 -0.13         | 0                  | 0.0-10.0                  | 6.0-10.0           | 124-140                         | 8.4-7.1            | 7.1-7.1     |  |
| Stony Point Depression                 |                        |                     |                          |                   |                    |                           |                    |                                 |                    |             |  |
| 1934                                   |                        |                     |                          |                   |                    |                           |                    |                                 |                    |             |  |
| July 5                                 | t. s.                  | c. s.               | 5.35-0.0                 | 3.3 -0.0          | 17-18              | 0.0-3.0                   | 0.0-2.0            | 128-132                         | 8.2-7.1            | 7.7-7.1     |  |
| Aug. 10                                | t. s.                  | c. gr.              | 5.78-0.0                 | 3.24-0.07         | 16-18              | 0.0-8.0                   | 1.0-7.0            | 120-136                         | 8.2-7.0            | 7.8-7.1     |  |
| 1937                                   |                        |                     |                          |                   |                    |                           |                    |                                 |                    |             |  |
| Aug. 9                                 | t. gr.                 | c. gr.              | 6.0 -1.0                 | No strat.         | 0                  | 0.0-7.0                   | .....              | 128-136                         | 8.2-7.4            | .....       |  |
| 1939                                   |                        |                     |                          |                   |                    |                           |                    |                                 |                    |             |  |
| July 19                                | t. s.                  | c. s.               | 5.5 -0.9                 | 2.3 -1.9          | 0                  | 0.0-3.0                   | 1.0-1.5            | 124-122                         | 8.2-7.2            | 7.4-7.4     |  |
| 1940                                   |                        |                     |                          |                   |                    |                           |                    |                                 |                    |             |  |
| July 23                                | t. s.                  | c. s.               | 5.57-2.01                | 5.57-5.6          | 0                  | 0.0-3.0                   | 0.0-0.0            | 120-129                         | 8.2-7.3            | 8.2-8.2     |  |
|                                        |                        |                     |                          | 5.8 -5.6          |                    |                           | 0.0-0.0            |                                 |                    | 8.2-8.2     |  |
| Aug. 13                                | t. s.                  | c. s.               | 5.37-0.06                | 5.24-0.36         | 0                  | 0.0-6.0                   | 0.0-4.0            | 115-131                         | 8.2-7.2            | 8.0-7.3     |  |
| 1941                                   |                        |                     |                          |                   |                    |                           |                    |                                 |                    |             |  |
| Aug. 2                                 | t. gr.                 | c. gr.              | 5.23-2.14                | No strat.         | 0                  | 0.0-3.0                   | .....              | 120-130                         | 8.4-7.4            | .....       |  |

TABLE II (Continued)

| Date                     | Temperature conditions | Chemical conditions | Dissolved oxygen         |                      |                    | Free CO <sub>2</sub>      |                    | Methyl-orange alkalinity p.p.m. | pH                 |                    |
|--------------------------|------------------------|---------------------|--------------------------|----------------------|--------------------|---------------------------|--------------------|---------------------------------|--------------------|--------------------|
|                          |                        |                     | Surface and bottom cc./l | Thermocline cc./l    | Oxygenless zone m. | Surface and bottom p.p.m. | Thermocline p.p.m. |                                 | Surface and bottom | Thermocline        |
| Roberts Point Depression |                        |                     |                          |                      |                    |                           |                    |                                 |                    |                    |
| 1934<br>July 5           | t. s.                  | c. s.               | 5.16-0.0                 | 4.5 -1.54            | 19-22              | 0.0-4.0                   | 0.0-2.2            | 120-132                         | 8.2-7.0            | 8.0-7.3            |
| 1937<br>Aug. 9           | t. s.                  | c. s.               | 6.0 -0.0                 | 3.4 -0.0             | 17-22              | 0.0-10.0                  | 2.0-9.0            | 130-126                         | 8.2-7.1            | 7.7-7.2            |
| 1939<br>June 29          | t. s.                  | c. s.               | 5.6 -0.6                 | 5.7 -5.8<br>3.8 -0.4 | 0                  | 0.0-5.0                   | 0.0-0.0<br>1.0-5.0 | 117-129                         | 8.2-7.0            | 8.2-8.2<br>7.5-7.0 |
| July 17                  | t. s.                  | c. s.               | 5.6 -0.27                | 5.2 -1.2             | 0                  | 0.0-8.0                   | 0.0-2.5            | 116-124                         | 8.2-7.1            | 8.0-7.3            |
| Aug. 10                  | t. s.                  | c. s.               | 4.8 -0.07                | 4.7 -0.07            | 0                  | 0.0-7.0                   | 0.0-6.0            | 121-130                         | 8.2-7.0            | 8.0-7.0            |
| 1940<br>July 9           | t. s.                  | c. s.               | 5.27-1.36                | 5.2 -5.4<br>5.6 -5.6 | 0                  | 0.0-1.5                   | 0.0-1.5            | 120-125                         | 8.2-7.2            | 7.8-7.3            |
| Aug. 1                   | t. s.                  | c. s.               | 5.4 -0.7                 | 4.5 -1.9             | 0                  | 0.0-5.0                   | 0.0-0.0            | 118-128                         | 8.1-7.1            | 8.1-7.7            |
| Aug. 17                  | t. s.                  | c. s.               | 5.3 -0.0                 | 5.4 -4.3<br>4.0 -1.5 | 18-22              | 0.0-10.0                  | 0.0-4.0            | 116-128                         | 8.2-7.1            | 7.8-7.4            |
| 1941<br>July 29          | t. s.                  | c. s.               | 5.23-0.0                 | 4.56-0.1             | 18-22              | 0.0-12.0                  | 0.0-11.0           | 129-134                         | 8.3-7.0            | 8.1-7.0            |



TABLE II (Concluded)

| Date                      | Temperature conditions | Chemical conditions | Dissolved oxygen         |                   |                    | Free CO <sub>2</sub>      |                    | Methyl-orange alkalinity p.p.m. | pH                 |             |
|---------------------------|------------------------|---------------------|--------------------------|-------------------|--------------------|---------------------------|--------------------|---------------------------------|--------------------|-------------|
|                           |                        |                     | Surface and bottom cc./l | Thermocline cc./l | Oxygen-les zone m. | Surface and bottom p.p.m. | Thermocline p.p.m. |                                 | Surface and bottom | Thermocline |
| Fairy Island Depression   |                        |                     |                          |                   |                    |                           |                    |                                 |                    |             |
| 1934<br>July 2<br>Aug. 6  | t. s.                  | c. s.               | 5.79-0.0                 | 4.55-2.34         | 24-27              | 0.0-9.0                   | 0.5-5.0            | 111-127                         | 8.0-8.9            | 7.6-7.3     |
|                           | t. s.                  | c. s.               | 5.77-0.0                 | 4.5 -0.0          | 17-27              | 0.0-9.0                   | 1.0-5.0            | 128-134                         | 8.2-7.0            | 7.6-7.1     |
| 1937<br>Aug. 11           | t. s.                  | c. s.               | 4.9 -0.0                 | 3.2 -0.1          | 18-27              | 0.0-10.0                  | 3.0-9.0            | 128-130                         | 8.2-7.1            | 7.6-7.2     |
|                           | t. s.                  | c. s.               | 5.7 -0.07                | 5.1 -4.8          | 25-27              | 0.0-6.0                   | 0.0-0.0            | 120-124                         | 8.2-7.0            | 8.1-8.0     |
| 1939<br>July 4<br>July 18 | t. s.                  | c. s.               | 5.6 -0.0                 | 4.5 -0.8          | 19-27              | 0.0-9.0                   | 0.0-4.0            | 114-121                         | 8.2-7.0            | 7.9-7.1     |
|                           | t. s.                  | c. s.               | 5.33-0.0                 | 5.36-5.56         | 26-27              | 0.0-7.0                   | 0.0-0.0            | 117-127                         | 8.3-7.0            | 8.3-8.3     |
| 1940<br>July 13           | t. s.                  | c. s.               |                          | 4.02-1.94         |                    |                           | 1.0-2.5            |                                 |                    | 7.7-7.2     |
|                           | t. s.                  | c. s.               | 5.57-0.0                 | 6.0 -3.3          | 26-27              | 0.0-9.0                   | 0.0-0.0            | 117-127                         | 8.3-7.1            | 8.3-8.0     |
| Aug. 1                    | t. s.                  | c. s.               |                          | 1.5 -1.0          |                    |                           | 3.0-5.0            |                                 |                    | 7.4-7.3     |
|                           | t. s.                  | c. s.               | 5.3 -0.0                 | 5.24-1.96         | 26-27              | 0.0-12.0                  | 0.0-4.0            | 114-132                         | 8.2-7.0            | 8.2-7.3     |
| Aug. 17                   |                        |                     |                          |                   |                    |                           |                    |                                 |                    |             |
| 1941<br>July 29           | t. s.                  | c. s.               | 5.50-0.0                 | 2.68-0.06         | 21-27              | 0.0-12.0                  | 3.0-10.0           | 128-132                         | 8.3-7.0            | 7.4-7.0     |

# A STUDY OF THE SEDIMENT IN DOUGLAS LAKE, CHEBOYGAN COUNTY, MICHIGAN

IRA T. WILSON

**I**N ORDER TO study the sediment in Douglas Lake, located in Cheboygan County, Michigan, one hundred and eleven borings were made to the original bottom of the lake. Since an excellent contour map of the present basin (Fig. 1) was already available, the data secured from the borings were limited to the construction of contour maps of the original basin (Fig. 2), and of a later stage called the "high-level stage" (Fig. 3), and of profile diagrams (Fig. 4), which show the relationship of the original, high-level, and present basins to one another. The contour maps furnished the basis for determining the various morphometrical features (summarized in Table II) of the different basins as wholes and also for the many separate depressions for which the lake is notable.

Most of the borings were exploratory in the sense that they were made rapidly with the intention of discovering only the type of sediment and the depth of the transitional zones between the various kinds of sediment. Nine borings were made, however, in different parts of the lake from which complete cores of sediment were taken. These furnished a careful check on the conclusions based on the exploratory borings and gave material for the study of the chemical and petrographic nature of the sediment and the microfossils and laminations found in it. The fossil pollen from one boring (No. 74 in South Fish-Tail Bay, Fig. 1) has been examined and forms the subject of a paper already published (Wilson and Potzger, 1943). Dr. Ruth Patrick is studying the diatoms and Dr. Frank E. Eggleton the invertebrates from the cores; if the material warrants, they will make separate publications of it. The laminations in the sediment have proved profitable for the construction of a postglacial timetable, which will be the subject of still another paper in the near future.

## ACKNOWLEDGMENTS

The major financial support for the field work was provided by the Institute for Fisheries Research, Ann Arbor, Michigan. The Michigan Academy of Science, Arts, and Letters, through grants-in-aid from the American Association for the Advancement of Science, contributed materially to this project. For lodging and laboratory space, shops, boats, and other facilities the writer wishes to thank the Biological Station of the University of Michigan, which is located on Douglas Lake.

The writer is indebted to John McQuate and John H. Thompson, Jr., who helped do the field work during the summer of 1942 and made many of the computations in determining the morphometrical constants, and to Philip Krause and Howard Poetter, who assisted in the field work in 1943. He is very grateful to the staff of the Biological Station for many suggestions and much help, and especially to Dr. A. H. Stockard, who made the arrangements for the work, as well as to Drs. Paul S. Welch, Frank E. Eggleton, Frank C. Gates, and Gerald W. Prescott for suggestions and considerable assistance in the interpretation of the findings. Special acknowledgment of aid is due to Dr. A. S. Hazzard, director of the Institute for Fisheries Research, for his keen interest in the work and for his securing the means to carry it out.

## METHODS

The methods used in making the borings and taking the samples of sediment are substantially those described earlier by the writer (Wilson, 1941). He would like to add, however, that he learned that in working from a float on a good-sized lake where the water is rough a considerable part of the time, it is essential to have one as broad as the length of the maximum waves in order to avoid rocking.

## A BRIEF HISTORY AND DESCRIPTION OF DOUGLAS LAKE

I. D. Scott (1921) describes Douglas Lake (Fig. 1) as having been "a depression in the bottom of one of the inlets of a great archipelago" during the existence of Lake Algonquin, and says that it became isolated as a separate body of water with the subsidence of the waters of Lake Algonquin. He continues his description as follows:

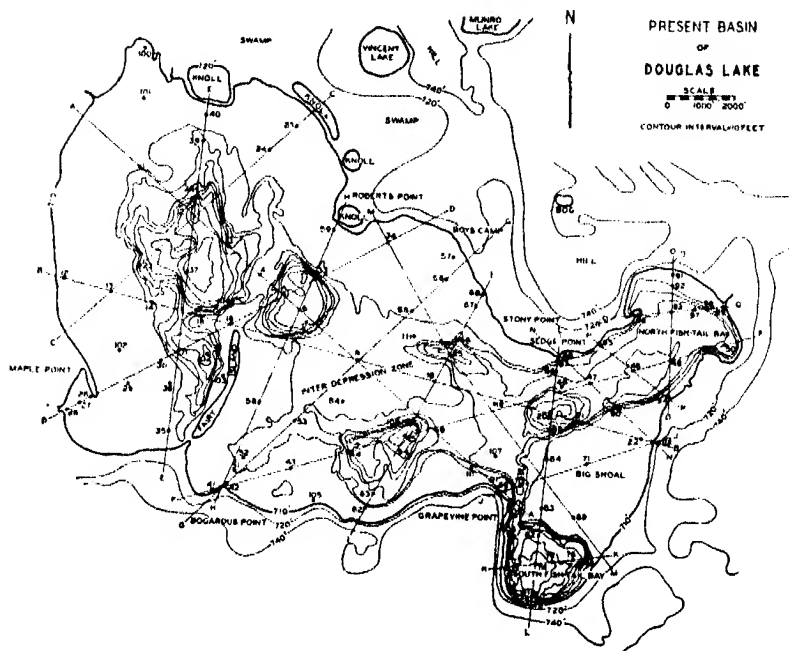


FIG. 1. Contour map of the present basin of Douglas Lake, showing the location of the 111 borings that form the basis of the maps of the original (Fig. 2) and high-level (Fig. 3) basins and the cross-section profiles (Fig. 4). It will be noted that (with few exceptions) the borings have been made along lines that cover the basin in all critical places. The lines are lettered (A-A, B-B, etc.) to correspond with the cross-section profiles in Figure 4. The names of the depressions can be determined by referring to Figure 2. The shoreline of this basin is 710 feet above sea level. The contours are taken from a map the contours of which were made by Dr. Paul S. Welch

The material surrounding the lake is all of glacial origin and is composed of sand, except at the headlands. These headlands are caused by till, which is much less readily attacked by the waves, and it will be seen from the map (Fig. 42)<sup>1</sup> that, in general, they are opposite each other. There seem to be two small till ridges here which cause the constrictions in the outline of the lake but do not persist across the basin unless possibly in the case of the more westerly. On either side and between the ridges are heavy deposits of sand which partially filled the depressions except where the lake now lies. The eastern end of the lake is surrounded by outwash but the sands of the central and western basins, although possibly outwash, were deposited, in part at least, on the bed of Lake Algonquin which formerly covered this region.

<sup>1</sup> The features referred to in this figure are also evident in Figure 1 of this paper.

The separate depressions found in Douglas Lake Scott assumed to be due to irregularities in one block of ice or to several separate blocks left by the melting ice sheet that had previously covered this region. This early period as an embayment of Lake Algonquin is referred to in this report as the Algonquin stage of the lake and the basin it occupied at the outset as the original basin. It was during this early period, according to Scott, that there was developed a broad terrace which still forms a conspicuous feature of the landscape

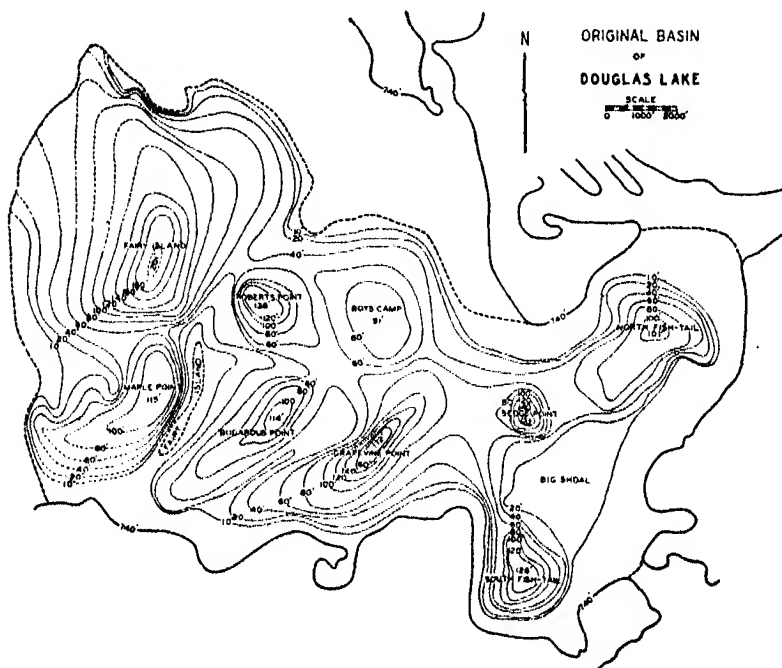


FIG. 2. Contour map of the original basin of Douglas Lake, showing the names and locations of the depressions. The data for the shoreline (where solid) were compiled from a topographical map of the Bogardus tract (south-eastern end of lake) drafted by the College of Engineering and the School of Forestry and Conservation of the University of Michigan and from measurements and elevations (outside the Bogardus tract) made by the writer. The dotted part of the shoreline was drawn arbitrarily a little way outside the present shoreline in order to have a basis for determining the morphometrical constants of the original basin; such a procedure was necessary since it was this part of the original basin that was confluent with greater Lake Algonquin. The shoreline is 740 feet above sea level

around the lake at approximately the 730-foot elevation above sea level (about 20 feet above the present lake level). If it is assumed that 10 feet of water stood above this terrace when it was cut, then the Algonquin water level would have had an elevation of 740 feet. This is the basis on which the writer used the 740-foot contour (Figs. 1-2) as marking the original shoreline (Algonquin stage) of the lake.

Scott explains that, when the greater Algonquin Lake lowered to the Nipissing level and Douglas Lake became an isolated body of

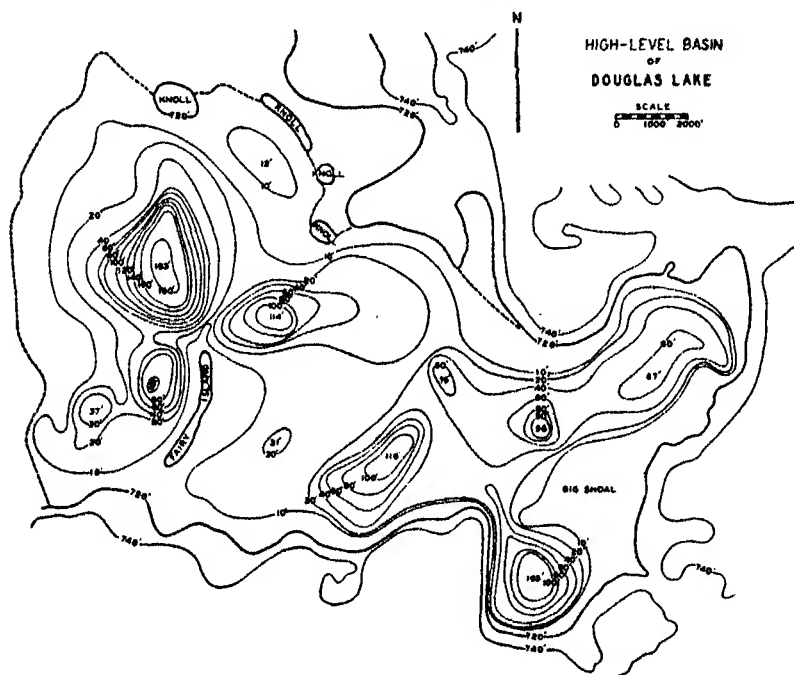


FIG. 3. Contour map of the high-level stage of Douglas Lake, that is, the basin at the end of the Algonquin stage. The depths were taken from the point of contact of the pink clay (Algonquin deposit) and black mud or marl (warm-water deposits). Data for the shoreline, which is 720 feet above sea level, were taken from a topographical map of the Bogardus tract (southeastern end of the lake) and measurements made by the writer. The dotted part of the shoreline was drawn arbitrarily just outside the present shoreline to form a basis for computing the morphometrical constants of the basin, since at this stage of the lake water covered several square miles of low sandy ground to the west and northwest which it did not seem practicable to include in this study

water, the surface of the lake was considerably higher than it is at present and that it was during this high-level stage that most of the shore adjustments were made that characterize the lake today. A broad wave-cut terrace about four feet above the present lake level was developed at this high-level stage. This terrace became exposed when the lake lowered to its present level, and if it is assumed that six feet of water stood above it, then the 720-foot contour can be used to mark the elevation of the water and shoreline for this stage of the lake, as was done in drafting Figures 1 and 3.

Welch (1927) and Welch and Eggleton (1932, 1935) have made special studies of the isolated submerged depressions that occur in Douglas Lake at the present time. There are seven such depressions, known as Fairy Island, Maple Point, Roberts Point, Grapevine Point, Stony Point, Sedge Point, and South Fish-Tail Bay (Fig. 2). The present study has revealed three additional depressions, now completely filled, as having existed in the past; they have been named Bogardus Point, Boys Camp, and North Fish-Tail Bay (Fig. 2). Undoubtedly these newly discovered depressions, like those known to Scott (1921), were caused by stranded blocks of ice from the receding Wisconsin ice sheet. Evidence will be submitted later suggesting that these dead blocks of ice remained in the several basins for varying lengths of time and thereby profoundly influenced the distribution of the sediment laid down during the early (Algonquin) stage of the lake.

#### NATURE AND DISTRIBUTION OF THE SEDIMENT

The sediment in Douglas Lake consists of four types, namely, gelatinous brown to black mud, marl, pink clay, and a brown varved clay. The gelatinous black mud forms the uppermost deposit and is soft for the first few feet, but becomes quite solid farther down and is almost like horn in the bottom reaches. The marl, which lies immediately below the black mud, is gray and rich in carbonates, being quite similar to that found at the surface in some lakes. Both the black mud and the marl are considered to be warm-water deposits (Fig. 4) and to have been laid down after Douglas Lake had become an isolated basin in which the water warmed and stratified in summer much as it does today; this would have been during the high-level and the present stages of the lake.

The pink clay is an amorphous deposit lying below the marl and is thought to have been made during the Algonquin period of the lake and, therefore, to have been a fairly cold-water deposit (Fig. 4). The fact that the water in Lake Algonquin probably had much of its source in the melting ice sheet implies the conclusion given above. The nearly complete lack of organic matter in the pink clay (Table I) and the fact that its color is due to the presence of iron oxide, which probably came from the iron deposits farther north, tend to confirm this interpretation.

The brown varved clay occurs in deposits about a foot thick in several localities in the lake basin below the pink-clay deposit. It was found near the surface at some places near shore, but was present below 104 feet of sediment (172 feet below the present water surface) at boring 2 (Fig. 1) in Fairy Island depression. Since this brown varved clay (often rather thick deposits) occurs over a wide area of this part of the State of Michigan, sometimes at levels higher than Lake Algonquin ever reached (Leverett and Taylor, 1915), it is likely that it antedates Douglas Lake. In Douglas Lake this deposit was always underlain with very fine sand that contains enough carbonates to give a vigorous reaction to hydrochloric acid. There was 41 feet of this fine sand lying under the brown clay at boring 42, below which is coarse gravel. If it should be ascertained that this clay layer is of earlier origin than the Algonquin stage of the lake, it could be utilized as a marker of the original bottom. This would remove some of the doubt expressed by the dotted lines on the map of the original basin (Fig. 2) and, consequently, reduce the volume of the original basin slightly.

That the sequence of deposits is not quite so simple as it appears from the foregoing description and the profile diagrams (Fig. 4), owing principally to the alternation of the various types of sediment at transitional zones between the major deposits, is shown by the following log of a core taken from the center of South Fish-Tail Bay depression: water, 72 feet; soft-flocculent black mud, 72-74 feet; gelatinous-laminated brown mud, 74-103 feet; gray marl, 103-106 feet; tough gelatinous-laminated black mud, 106-107 feet; gray marl, 107-108 feet; pink clay, 108-109 feet; sandy white clay, 109-109.5 feet; white and pink clay layers alternating, 109.5-112.5 feet; fine sand, 112.5-116 feet; sandy pink clay, 116-117 feet; dark-pink clay, 117-123 feet; sand, 123-123.5 feet; pink clay, 123.5-125 feet;



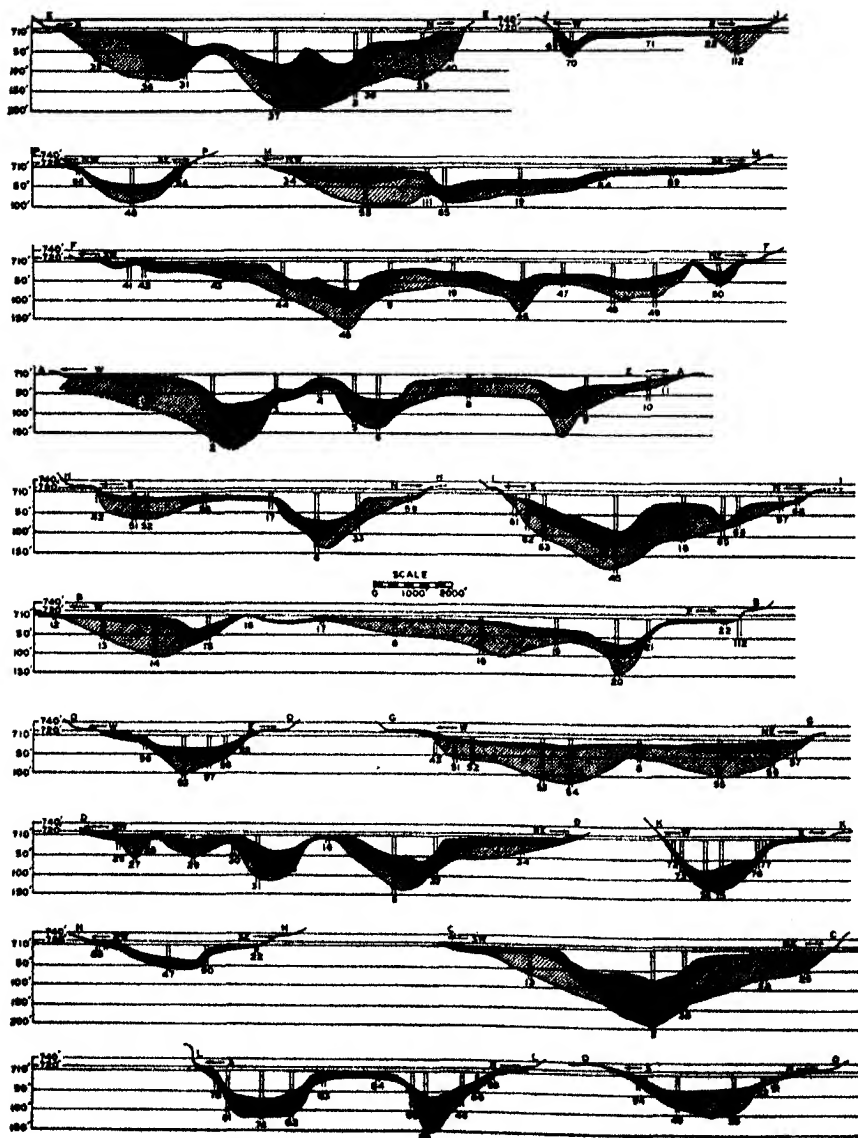


FIG. 4

(For the explanation of Figure 4 see the bottom of the facing page.)

sand, 125-126 feet; pink clay, 126-127 feet; sand, 127-127.5 feet; gray clay, 127.5-134 feet; fine sand, 134-135 feet; gray clay, 135-136 feet; fine sand, 136-137 feet; gray clay, 137-138 feet; coarse sand, 138-143 feet.

Table I gives a chemical and petrographic analysis for the four types of sediment listed above, namely, gelatinous black mud, gray marl, pink clay, and brown varved clay. The analyses were made by the laboratories of the Basic Refractories, Inc., of Tiffin, Ohio, to which the writer is indebted. The method of chemical analysis was that ordinarily used with limestone. Miss Elizabeth Haley, of the laboratory, who did the petrographic analyses, found it impossible to separate the material by the usual methods, owing to the large amount of calcite and organic matter present. She says: "No attempt was made to distinguish the various clay minerals — kaolin, dickite, sericite, etc. — and a complete identification of all minerals present was not undertaken." The analysis gives a good idea, however, of the relative abundance of the principal minerals.

The analysis of the black mud shows it to be mostly water (75 per cent). This is due to its gelatinous nature, because most of this water is an integral part of the jelly and cannot be removed by dehydration with alcohol. A sample taken from nearer the surface would have shown an even higher percentage of water. Exclusive of the water, a large part (30 per cent) of this sediment is organic matter in which pollen grains and fragments of plants can be recognized. Silicon dioxide makes up 48.80 per cent of this sediment (dry weight), which microscopic examination shows to be mostly the tests of diatoms. Quartz, calcite, and limonite were recognized in the petrographic analysis, their importance being in the order given.

The marl sample analyzed, although appearing to be no firmer than the gelatinous sediment, contained only 47.99 per cent of water. On the basis of dry weight there are considerable quantities of organic

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#### EXPLANATION OF FIGURE 4

Cross-section profiles, showing the relationship of the basins of the three stages of Douglas Lake. The bottom line represents the original basin; the middle line (border crosshatched and black), the high-level basin; and the top line, the present basin. The crosshatched areas indicate the pink-clay deposit of the Algonquin stage, and the shaded portion (warm-water deposit) represents the marl (lower part usually only a few feet) and black mud that accumulated during the high-level and present stages. The locations of these cross sections are given in Figure 1

matter (11.30 per cent) and silicon dioxide (27.20 per cent). The carbonates (mostly calcium and magnesium) form a large proportion of the sediment (approximately 50 per cent), mostly in the form of calcite and dolomite. There was a small quantity of kaolins, also.

By dry weight the pink clay is 48.20 per cent silicon dioxide,

TABLE I

ANALYSES OF SELECTED SAMPLES FROM BORING 74 IN  
SOUTH FISH-TAIL BAY DEPRESSION

| Sample composition                  | Gelatinous<br>black<br>mud | Marl  | Pink clay | Brown varved<br>clay<br>(near Burt Lake) |
|-------------------------------------|----------------------------|-------|-----------|------------------------------------------|
| Depth of water (feet)               | 69                         | 69    | 69        | 15 (above sur-<br>face)                  |
| Depth below water<br>surface (feet) | 77-94                      | 98-99 | 109-110   | 15 (above sur-<br>face)                  |

Chemical constituents  
(Percentage — dry weight)

|                                              |                    |       |                   |       |
|----------------------------------------------|--------------------|-------|-------------------|-------|
| SiO <sub>2</sub> .....                       | 48.80<br>(Diatoms) | 27.20 | 48.20<br>(Quartz) | 38.34 |
| R <sub>2</sub> O <sub>3</sub> .....          | 6.00               | 6.00  | 12.36             | 10.85 |
| CaO .....                                    | 4.20               | 24.00 | 9.55              | 15.35 |
| MgO .....                                    | 1.30               | 3.80  | 7.84              | 8.14  |
| Loss on ignition .....                       | 35.00              | 34.35 | 16.60             | 21.68 |
| Calculated amount of<br>organic matter ..... | 30.00              | 11.30 | 1.00              | None  |

Petrographic analyses

|                                        |                                |                                                                   |                                                                                     |                                                                                                 |
|----------------------------------------|--------------------------------|-------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
| Color of wet samples                   | Black                          | Grayish<br>green                                                  | Brown                                                                               | Pinkish tan                                                                                     |
| Color of dry samples                   | Gray green                     | Gray                                                              | Tan                                                                                 | Pinkish tan                                                                                     |
| Color after leaching<br>with HCL ..... | Brownish<br>gray               | Dark olive<br>green brown<br>when dried                           |                                                                                     | Blue gray                                                                                       |
| Loss of water on dry-<br>ing .....     | 75.00 %                        | 47.99 %                                                           | 34.24 %                                                                             | Large quantity                                                                                  |
| Names of minerals ..                   | Quartz*<br>Calcite<br>Limonite | Calcite*<br>Dolomite<br>Kaolins<br>Quartz<br>Limonite<br>Feldspar | Dolomite*<br>Clay<br>Quartz<br>Feldspar<br>Iron oxide<br>Titanite (?)<br>Zircon (?) | Dolomite*<br>Calcite<br>Kaolins<br>Quartz<br>Limonite<br>Feldspar<br>Titanite (?)<br>Zircon (?) |

\* In order of abundance.

nearly all in the form of quartz. The percentage of magnesium oxide is higher than in the marl, and that of calcium oxide is lower; these minerals occur mostly in the form of dolomite. The  $R_2O_3$  compounds are more abundant, probably owing to the increase in aluminum oxide found in the higher proportions of clay and feldspar present. The iron oxide in this sediment undoubtedly accounts for its characteristic pink color. The large amount of clay causes the physical appearance of the sediment. Organic matter constitutes only 1 per cent and, therefore, is almost entirely absent from this material; it is made up to some extent of pollen grains.

The brown varved clay is much like the pink clay, except that considerable calcite as well as limonite is present; the limonite accounts for the brown color. The number of varves ranges from 10 to 30 per inch, and they indicate that the deposit was laid down in cold water, since they do not form in water over 10 degrees centigrade.

The distribution of the warm- and the cold-water types of sediment is indicated on the profile drawings (Fig. 4). The black shaded portions of the profiles represent the gelatinous black mud and the marl; the marl makes up only a few feet of this part of the deposit near the bottom. The crosshatched portion of the profiles indicates the pink-clay deposit. By means of graphs, Figure 5 gives a good idea of the distribution of the sediment in the various separate depressions and in the lake as a whole.

## MORPHOMETRICAL CHANGES IN THE BASINS

### 1. INTRODUCTION

Reference has been made to the fact that Douglas Lake has passed through three stages, namely, (1) the Algonquin, at which time it formed an embayment in the great postglacial Lake Algonquin, (2) the high-level stage, which began when Lake Algonquin receded to the Nipissing level and isolated the Douglas-Lake embayment, and (3) the present stage, which is approximately ten feet lower than the high-level stage. There is no way to distinguish between the sedimentary deposits laid down during the high-level and the present stages; consequently the comparisons between stages are between the basins of the beginning of the Algonquin stage (original basin), of the beginning of the high-level stage (high-level basin), and of today. At the west end of the lake the study of the morphometry of the

original and high-level basins has been restricted to the region of the present basin, in spite of the existence of a broad contiguous plain extending several miles beyond that was covered with water during the Algonquin and high-level stages. The character of the deposit over this plain indicates that it resulted more from forces within the main body of Lake Algonquin than from the forces prevailing within the embayment that subsequently formed Douglas Lake.

In this section of the report four things will be described: (1) the three stages of each depression (with a comparison of similar morphometrical features included); (2) the three stages of the lake as a whole; (3) certain boulder belts; and (4) unusual sand deposits found in some depressions. The morphometrical data for all the depressions and for the lake as a whole are tabulated in Table II, together with the percentages of change that took place between the stages. It should be kept in mind that in the morphometrical computations each depression was considered as if the topmost complete contour (isolation contour) were its shoreline and marked the surface level of the depression. Obviously, from this point of view, all the depressions were submerged many feet below the general surface water of the lake and, consequently, were removed from the influences of wave action. No other way to work out the morphometrical features for purposes of comparison seemed feasible.

## 2. DESCRIPTIONS OF THE DEPRESSIONS AND COMPARISON OF THE MORPHOMETRICAL FEATURES OF THE THREE STAGES

*Fairy Island depression.* — This depression (Figs. 1-3) is by far the largest of all the depressions in Douglas Lake at all three stages, as is indicated by the areas at the various isolation contours (60 feet for the original basin; 50 feet for the high-level; and 40 feet for the present basin). The original Fairy Island depression has an area of 27,590,000 sq. ft., the high-level stage 9,063,000 sq. ft., and the present basin 7,042,000 sq. ft. This is a decrease of 67.15 per cent from the original to the high-level stage and of 22.30 per cent from the high-level to the present stage. Such a marked decrease in area from the original to the high-level basins indicates a tremendous accumulation of sediment around the periphery of the basin during the Algonquin stage.

The data given above and all other data referred to in this section will be found in tabular form in Table II.

The maximum depth of Fairy Island depression increased from 141 to 143 feet from the original to the high-level stage and the mean depth from 46.44 to 69.35 feet, which shows that scarcely any of the sediment settled in the center of the basin during Algonquin time. In great contrast there was a decrease of 66.72 per cent (from 69.35 to 23.08 feet) in mean depth after the beginning of the high-level stage; these changes, together with the rather small decrease in area (22.30 per cent), indicate that practically all the sediment settled in the center of the basin during this time. By looking at the graph (Fig. 5) the changes noted above can be visualized.

The reduction in volume from the original (1,281,430,000 cu. ft.) to the high-level (628,599,000 cu. ft.) stage was 50.94 per cent as contrasted with a reduction of 74.14 per cent from the high-level to the present stage (162,567,000 cu. ft.). The absolute amounts of the reductions in volume were 652,831,000 and 466,032,000 cu. ft., respectively.

In view of the contrasting changes in area and maximum and mean depths during the Algonquin and subsequent stages of the lake, it is not surprising to find that the mean slope increased from 5.19 to 11.95 per cent during the former period and decreased from 11.95 to 5.92 per cent during the latter one.

There was an increase in volume development of 40.00 per cent from the original (1.0) to the high-level (1.4) basins. In contrast to this there was no change from the high-level (1.4) to the present (1.4) basins.

The length of the shoreline decreased from the original (21,250 feet) to the high-level (11,750 feet) basin by 44.70 per cent but increased by 13.19 per cent from the high-level to the present (13,300 feet) basin. Shore development did not change during the Algonquin stage but increased 27.27 per cent (1.1 to 1.4) during the subsequent period. These figures are significant so far as the original to high-level changes are concerned, but are not so dependable in comparing the high-level to the present basin because the "shoreline" (isolation contour) of the present basin was determined from so many more soundings than those of the other two basins were that it shows many irregularities overlooked in the two earlier basins.

The volume of sediment (Table III) laid down during the Algonquin stage was 836,101,000 cu. ft. and that laid down subsequently, that is, since the beginning of the high-level stage, is 546,560,000

TABLE

## SUMMARY OF ALL MORPHOMETRICAL

All morphometrical computations for the depressions were made as if the top-order to make comparisons more meaningful for the lake as a whole the maximum the surface of the present basin marked the surfaces of all three stages.

| NAME OF DEPRESSION  | AREA<br>(Square feet) |             |             | MAXIMUM DEPTH<br>(Feet) |            |         |
|---------------------|-----------------------|-------------|-------------|-------------------------|------------|---------|
|                     | Original              | High level  | Present     | Original                | High level | Present |
| Fairy Island        | 27,590,000            | 9,063,000   | 7,042,000   | 141                     | 143        | 49      |
| % of change         | - 87.15 *             | - 22.30 *   |             | + 1.42                  | - 65.73    |         |
|                     |                       | - 74.46 *   |             | - 65.25                 |            |         |
| Grapevine Point     | 9,192,000             | 6,799,000   | 3,936,000   | 102                     | 88         | 51      |
| % of change         | - 26.03               | - 42.04     |             | - 13.72                 | - 42.05    |         |
|                     |                       | - 57.17     |             | - 50.00                 |            |         |
| Boys Camp           | 6,737,000             | 0.0         | 0.0         | 31                      | 0.0        | 0.0     |
| % of change         | - 100.00              | 0.0         |             | - 100.00                | 0.0        |         |
|                     |                       | - 100.00    |             | - 100.00                |            |         |
| Maple Point         | 6,412,000             | 1,886,000   | 637,000     | 55                      | 51         | 11      |
| % of change         | - 70.57               | - 66.25     |             | - 7.27                  | - 78.43    |         |
|                     |                       | - 90.06     |             | - 80.00                 |            |         |
| North Fish-Tail Bay | 5,473,000             | 3,732,000   | 1,503,000   | 41                      | 17         | 4       |
| % of change         | - 31.81               | - 59.73     |             | - 58.54                 | - 76.47    |         |
|                     |                       | - 72.54     |             | - 90.24                 |            |         |
| Bogardus Point      | 4,859,000             | 7,459,000   | 1,920,000   | 64                      | 11         | 9       |
| % of change         | + 74.09               | - 74.26     |             | - 82.81                 | - 18.18    |         |
|                     |                       | - 60.49     |             | - 85.94                 |            |         |
| Roberts Point       | 3,906,000             | 11,897,000  | 3,880,000   | 78                      | 94         | 52      |
| % of change         | + 204.66              | - 67.38     |             | + 20.51                 | - 44.66    |         |
|                     |                       | - 0.64      |             | - 33.33                 |            |         |
| South Fish-Tail Bay | 2,663,000             | 4,522,000   | 3,926,000   | 56                      | 63         | 43      |
| % of change         | + 69.78               | - 13.17     |             | + 12.50                 | - 31.75    |         |
|                     |                       | + 47.40     |             | - 23.21                 |            |         |
| Sedge Point         | 1,681,000             | 2,426,000   | 1,835,000   | 83                      | 46         | 39      |
| % of change         | + 44.31               | - 24.37     |             | - 44.58                 | - 15.23    |         |
|                     |                       | + 9.13      |             | - 53.01                 |            |         |
| Stony Point         | 0.0                   | 725,000     | 701,000     | 0.0                     | 25         | 19      |
| % of change         | 0.0                   | - 3.24      |             | 0.0                     | - 24.00    |         |
|                     |                       | 0.0         |             | 0.0                     |            |         |
| Whole lake          | 199,465,000           | 173,458,000 | 160,088,000 | 201                     | 193        | 89      |
| % of change         | - 13.04               | - 7.71      |             | - 3.96                  | - 53.89    |         |
|                     |                       | - 19.74     |             | - 55.72                 |            |         |

\* These figures and others in the same relative position represent the percentage of change for the figures between which they lie.

## II

## DATA FOR DOUGLAS LAKE

most complete contour of a depression were the "surface" of the basin. In depth, mean depth, volume development, and mean slope were calculated as if

| MEAN DEPTH<br>(Feet) |            |         | VOLUME<br>(Cubic feet) † |               |               |
|----------------------|------------|---------|--------------------------|---------------|---------------|
| Original             | High level | Present | Original                 | High level    | Present       |
| 46.44                | 69.35      | 23.08   | 1,281,430,000            | 628,599,000   | 162,567,000   |
| +49.33               | -66.72     |         | -50.94                   | -74.14        |               |
|                      | -50.30     |         |                          | -87.31        |               |
| 29.18                | 35.73      | 18.80   | 268,235,000              | 242,918,000   | 74,037,000    |
| +22.45               | -47.38     |         | -9.44                    | -69.52        |               |
|                      | -35.57     |         |                          | -72.40        |               |
| 16.65                | 0.0        | 0.0     | 112,248,000              | 0.0           | 0.0           |
| -100.00              |            | 0.0     | -100.00                  |               | 0.0           |
|                      | -100.00    |         |                          | -100.00       |               |
| 27.76                | 25.83      | 5.86    | 188,022,000              | 48,736,000    | 3,739,000     |
| -6.95                | -77.31     |         | -74.08                   | -92.33        |               |
|                      | -78.89     |         |                          | -98.01        |               |
| 21.45                | 15.35      | 1.33    | 117,428,000              | 31,107,000    | 2,004,000     |
| -28.45               | -91.33     |         | -73.51                   | -93.56        |               |
|                      | -93.80     |         |                          | -98.29        |               |
| 20.01                | 5.26       | 7.59    | 107,278,000              | 39,242,000    | 14,578,000    |
| -73.71               | +44.30     |         | -63.42                   | -62.85        |               |
|                      | -62.07     |         |                          | -86.41        |               |
| 29.02                | 25.26      | 29.92   | 113,361,000              | 300,599,000   | 116,167,000   |
| -12.96               | +18.49     |         | +165.17                  | -61.35        |               |
|                      | +3.08      |         |                          | +2.47         |               |
| 32.00                | 37.17      | 24.25   | 85,260,000               | 168,099,000   | 95,223,000    |
| +16.16               | -34.76     |         | +97.16                   | -43.35        |               |
|                      | -24.22     |         |                          | +11.68        |               |
| 33.50                | 16.76      | 16.45   | 56,326,000               | 40,660,000    | 30,186,000    |
| -49.97               | -1.84      |         | -27.81                   | -25.76        |               |
|                      | -50.90     |         |                          | -46.41        |               |
| 0.0                  | 10.19      | 6.93    | 0.0                      | 7,386,000     | 4,859,000     |
| 0.0                  | -32.00     |         | 0.0                      | -34.21        |               |
|                      | 0.0        |         |                          | 0.0           |               |
| 47.87                | 28.64      | 18.17   | 14,942,574,000           | 6,634,224,000 | 2,908,403,000 |
| -40.19               | -36.59     |         | -55.60                   | -56.16        |               |
|                      | -62.03     |         |                          | -80.54        |               |

† The detailed tables showing the volumes by frusta are on file in the Institute for Fisheries Research at Ann Arbor, Michigan.



TABLE

| NAME OF<br>DEPRESSION | VOLUME DEVELOPMENT |            |         | MEAN SLOPE<br>(Percentage) |            |         |
|-----------------------|--------------------|------------|---------|----------------------------|------------|---------|
|                       | Original           | High level | Present | Original                   | High level | Present |
| Fairy Island          | 1.0                | 1.4        | 1.4     | 5.19                       | 11.95      | 5.92    |
| % of change           | +40.00             | 0.0        |         | +130.25                    | -50.46     |         |
|                       |                    | +40.00     |         | +14.02                     |            |         |
| Grapevine Point       | 0.9                | 1.2        | 1.1     | 7.08                       | 7.99       | 6.07    |
| % of change           | +33.33             | -8.33      |         | +12.85                     | -24.03     |         |
|                       |                    | +22.22     |         | -14.26                     |            |         |
| Boys Camp             | 1.6                | 0.0        | 0.0     | 2.32                       | 0.0        | 0.0     |
| % of change           | -100.00            | 0.0        |         | -100.00                    | 0.0        |         |
|                       |                    | -100.00    |         | -100.00                    |            |         |
| Maple Point           | 1.5                | 1.5        | 1.6     | 6.25                       | 8.05       | 2.78    |
| % of change           | 0.0                | +6.67      |         | +28.80                     | -65.46     |         |
|                       |                    | +6.67      |         | -55.52                     |            |         |
| North Fish-Tail Bay   | 1.6                | 2.7        | 1.0     | 4.50                       | 1.78       | 0.99    |
| % of change           | +68.75             | -62.96     |         | -60.44                     | -44.32     |         |
|                       |                    | -37.50     |         | -78.00                     |            |         |
| Bogardus Point        | 0.9                | 1.4        | 2.5     | 6.34                       | 0.51       | 1.87    |
| % of change           | +55.56             | +78.57     |         | -91.89                     | +204.78    |         |
|                       |                    | +177.78    |         | -70.23                     |            |         |
| Roberts Point         | 1.1                | 0.8        | 1.7     | 7.93                       | 4.77       | 6.84    |
| % of change           | -27.27             | +112.50    |         | -38.85                     | +43.40     |         |
|                       |                    | +54.54     |         | -13.73                     |            |         |
| South Fish-Tail Bay   | 1.7                | 1.8        | 1.7     | 8.92                       | 8.01       | 6.55    |
| % of change           | +5.88              | -5.65      |         | -10.20                     | -18.23     |         |
|                       |                    | 0.0        |         | -26.57                     |            |         |
| Sedge Point           | 1.2                | 1.1        | 1.3     | 13.49                      | 5.49       | 6.55    |
| % of change           | -8.33              | +18.18     |         | -59.30                     | +19.31     |         |
|                       |                    | +8.33      |         | -51.44                     |            |         |
| Stony Point           | 0.0                | 1.2        | 1.1     | 0.0                        | 5.72       | 4.55    |
| % of change           | 0.0                | -8.33      |         | 0.0                        | -20.45     |         |
|                       |                    | 0.0        |         | 0.0                        |            |         |
| Whole lake            | 0.7                | 0.5        | 0.6     | 5.89                       | 3.72       | 2.81    |
| % of change           | -28.57             | +20.00     |         | -36.86                     | -24.44     |         |
|                       |                    | -14.29     |         | -52.29                     |            |         |

## II (Continued)

| LENGTH OF SHORELINE<br>(Feet)<br>(Isolation contours) |            |         | SHORELINE<br>DEVELOPMENT |            |         | AVERAGE DEPTH<br>OF SEDIMENT†<br>(Feet) |                    |                  | ISOLATION<br>CONTOUR |            |         |
|-------------------------------------------------------|------------|---------|--------------------------|------------|---------|-----------------------------------------|--------------------|------------------|----------------------|------------|---------|
| Original                                              | High level | Present | Original                 | High level | Present | Original high level                     | High level present | Original present | Original             | High level | Present |
| 21,250                                                | 11,750     | 13,300  | 1.1                      | 1.1        | 1.4     | 30.30                                   | 60.30              | 53.10            | 60                   | 50         | 40      |
| -44.70                                                | +13.19     |         | 0.0                      | +27.27     |         |                                         |                    |                  |                      |            |         |
| -37.41                                                |            |         |                          | +27.27     |         |                                         |                    |                  |                      |            |         |
| 14,100                                                | 10,450     | 9,000   | 1.3                      | 1.1        | 1.3     | 37.55                                   | 24.84              | 49.68            | 70                   | 30         | 30      |
| -25.89                                                | -13.87     |         | -15.38                   | +18.18     |         |                                         |                    |                  |                      |            |         |
| -36.17                                                |            |         | 0.0                      |            |         |                                         |                    |                  |                      |            |         |
| 9,800                                                 | 0.0        | 0.0     | 1.1                      | 0.0        | 0.0     | 15.18                                   | 0.0                | 15.18            | 60                   | 0          | 0       |
| -100.00                                               | 0.0        |         | 0.0                      | 0.0        |         |                                         |                    |                  |                      |            |         |
| -100.00                                               |            |         | 0.0                      |            |         |                                         |                    |                  |                      |            |         |
| 11,850                                                | 5,100      | 4,950   | 1.3                      | 1.0        | 1.7     | 28.19                                   | 30.53              | 39.73            | 60                   | 50         | 40      |
| -56.96                                                | -29.41     |         | -23.08                   | +70.00     |         |                                         |                    |                  |                      |            |         |
| -58.23                                                |            |         |                          | +30.77     |         |                                         |                    |                  |                      |            |         |
| 10,100                                                | 9,100      | 7,450   | 1.2                      | 1.3        | 1.7     | 24.18                                   | 29.30              | 33.83            | 60                   | 50         | 40      |
| -9.90                                                 | -18.13     |         | +8.33                    | +30.77     |         |                                         |                    |                  |                      |            |         |
| -26.24                                                |            |         |                          | +41.67     |         |                                         |                    |                  |                      |            |         |
| 10,250                                                | 11,500     | 8,000   | 1.3                      | 1.2        | 1.6     | 52.03                                   | 11.56              | 59.08            | 50                   | 20         | 10      |
| +12.19                                                | -30.43     |         | -7.93                    | +33.33     |         |                                         |                    |                  |                      |            |         |
| -21.95                                                |            |         |                          | +23.08     |         |                                         |                    |                  |                      |            |         |
| 7,400                                                 | 14,600     | 8,300   | 1.1                      | 1.2        | 1.2     | 32.98                                   | 15.50              | 39.15            | 60                   | 20         | 20      |
| +97.30                                                | -43.15     |         | +9.09                    | 0.0        |         |                                         |                    |                  |                      |            |         |
| +12.16                                                |            |         |                          | +9.09      |         |                                         |                    |                  |                      |            |         |
| 6,300                                                 | 10,300     | 9,100   | 1.1                      | 1.4        | 1.3     | 9.36                                    | 25.46              | 45.74            | 70                   | 40         | 30      |
| +63.49                                                | -11.65     |         | +27.27                   | -7.14      |         |                                         |                    |                  |                      |            |         |
| +44.44                                                |            |         |                          | +18.18     |         |                                         |                    |                  |                      |            |         |
| 5,300                                                 | 5,900      | 5,800   | 1.2                      | 1.1        | 1.2     | 33.75                                   | 13.10              | 46.91            | 70                   | 50         | 40      |
| +11.32                                                | -1.69      |         | -8.33                    | +9.09      |         |                                         |                    |                  |                      |            |         |
| +9.43                                                 |            |         | 0.0                      |            |         |                                         |                    |                  |                      |            |         |
| 0.0                                                   | 3,800      | 4,400   | 0.0                      | 1.3        | 1.5     | 0.0                                     | 13.32              | 0.0              | 0                    | 50         | 40      |
| 0.0                                                   | +15.78     |         | 0.0                      | +15.38     |         |                                         |                    |                  |                      |            |         |
| 0.0                                                   |            |         | 0.0                      |            |         |                                         |                    |                  |                      |            |         |
| ‡                                                     | ‡          | 74,400  | ‡                        | ‡          | 1.6     | 22.97                                   | 11.86              | 33.29            | -30                  | -10        | 0       |
| 0.0                                                   | 0.0        |         | 0.0                      | 0.0        |         |                                         |                    |                  |                      |            |         |
| 0.0                                                   |            |         | 0.0                      |            |         |                                         |                    |                  |                      |            |         |

‡ So much of the original and high-level shorelines was drawn arbitrarily that it makes futile a computation of their length and of their development.

§ The volume of sediment in each depression was computed as if the lower basin of any two lake stages, e.g., the original and the high level, included a special frustum extending from the topmost contour of the lower to the level of the topmost contour of the upper basin. In computing the *average depth of sediment* the total value for the quantity of sediment was always divided by the area of the topmost contour of the lower of the two basins being considered.

AVERAGE  
HEMISECTIONS OF DEPRESSIONS IN DOUGLAS LAKE

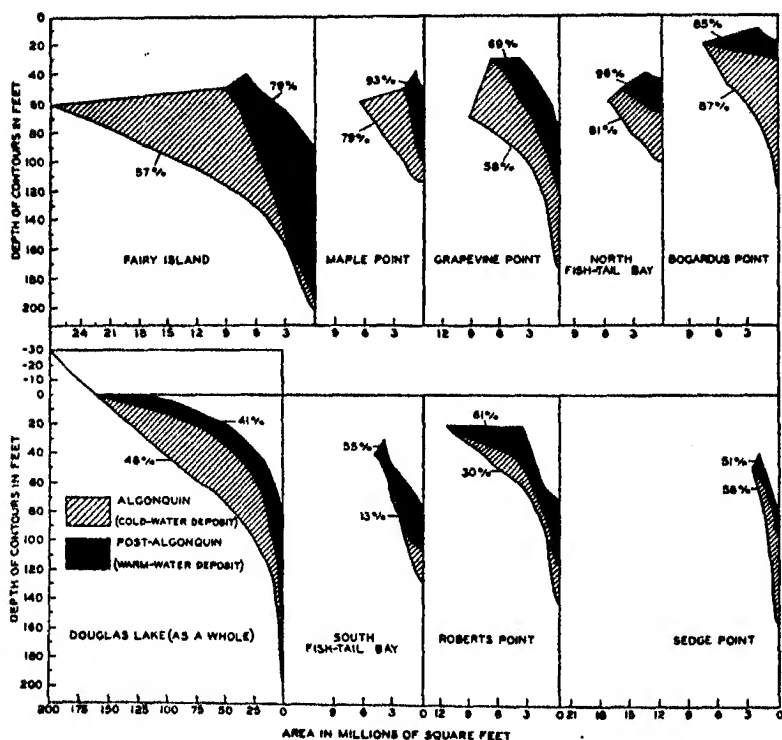


FIG. 5. Graphs made by plotting the areas within the various contours of the different stages of the depressions and the lake as a whole against the depths of the contours. They can be taken to represent average half cross sections of the depressions. The areas of the graphs between the curves for the different basins represent sediment. The graphs help one to visualize the parts of the basins in which the sediment accumulated at different stages as well as the changes in slopes, maximum depths, and other things. The percentages indicate the amount of filling of the basin in which they occur

cu. ft. Comparison of tables giving the volume of sediment by frusta (on file at the office of the Institute for Fisheries Research) shows that 50 per cent of the sediment laid down during the Algonquin stage lies above the base of the third frustum (30-foot contour), whereas 50 per cent of that deposited afterward (high-level and pres-

ent stages) lies above the base of the sixth frustum (60-foot contour). This difference follows from the fact that most of the sediment was laid down in the shallow periphery of the basin during the Algonquin stage but in the center during the later stages.

*Maple Point and Grapevine Point depressions.* — These two depressions resemble Fairy Island depression in that most of the pink-clay sediment characteristic of the Algonquin period of the lake settled around the periphery of the basin, whereas the reverse process (filling in the center) prevailed during the high-level and the present stages of the lake. This sequence of filling caused changes in the morphometrical features, from the original to the high-level stage on the one hand and from the high-level to the present stage on the other, to be about the same as those for the corresponding periods in Fairy Island depression. These resemblances can be verified by consulting Table II. Figure 5 shows the similarities graphically.

The three basins described so far, namely, Fairy Island, Maple Point, and Grapevine Point, were the largest and had the greatest maximum depth and volume of all the ten depressions in the original basin of Douglas Lake. They must have been formed by the largest blocks of ice. Their size, as will be shown later, probably is responsible for the peculiar manner in which they were filled as contrasted with that of the other basins.

*Bogardus Point depression.* — This depression differs radically from those already described in that it was almost completely filled with pink clay during the Algonquin stage of the lake. The difference is reflected to some extent in changes that have taken place in morphometrical features (Table II). During the Algonquin stage sediment settled in the center more rapidly than around the periphery (Fig. 5) and thus caused a reduction in maximum depth from 64 feet in the original basin to 11 feet in the high-level basin and a reduction in mean depth from 20.01 to 5.26 feet. An increase in area by 74.09 per cent (from 4,859,000 to 7,459,000 sq. ft.) from the original to the high-level basin emphasizes the fact that there was relatively little filling in of sediment around the edges of the basin. This is shown, also, by the accumulation of 84 feet of sediment in the center of the depression (boring 53), whereas the topmost contour (isolation contour) was raised only 30 feet during the Algonquin period. The reduction in volume (63.42 per cent) was likewise considerably greater than that in the Fairy Island depression, where the filling

was largely around the periphery during the same period. A reduction of 91.89 per cent in mean slope (from 6.34 to 0.51 per cent) during this period follows from the increase in area and the reduction in depth. Some decrease in irregularity in the shoreline is shown by the decrease in shoreline development from 1.3 to 1.2 per cent.

Owing to the more rapid accumulation of sediment around the periphery than in the center of the basin, shown by the reduction of 74.26 per cent in area and the relatively slight reduction in maximum depth of 18.18 per cent, the morphometrical changes in this depression during the time subsequent to the Algonquin period (the period of the high-level and the present basins) are of a kind diametrically opposite to those that took place from the original to the high-level basin. The volume was reduced by 62.85 per cent. The rate of reduction in area, which was faster than that in maximum depth, caused an increase in mean slope from 0.51 to 1.87 per cent.

The present basin of Bogardus Point depression is in reality only an embayment, but the mouth of the bay was arbitrarily taken as the limit of the lakeward side of the basin.

It is evident that Bogardus Point depression filled in a manner exactly opposite to that of Fairy Island, Maple Point, and Grapevine Point depressions at corresponding periods.

*Boys Camp depression.* — It is impossible to learn whether or not the filling of this basin took place more rapidly around the periphery than in the center, since the basin was completely obliterated during the Algonquin stage of the lake, but it undoubtedly did fill in the center at a rapid rate, which puts the basin in the same class as Bogardus Point depression during the Algonquin period. No filling has occurred since the Algonquin stage.

*South Fish-Tail Bay depression.* — Uniquely, no appreciable amount of sediment settled around the periphery, and very little did so in the center in the Algonquin stage of this depression (Fig. 5). The change in the isolation contour from 70 to 40 feet between the original and the high-level stages makes a deceiving situation, since it suggests considerable filling around the edge, but the 30-foot elevation is due to the plugging of a narrow channel connecting the depression to the main body of the lake (compare Figs. 2-3) and not to deposition within the basin itself. This elevating of the isolation contour is chiefly responsible for the increase in area (69.78 per cent),

maximum depth (12.50 per cent), mean depth (16.16 per cent), and volume (97.16 per cent). Since the area increased more than the maximum depth, the mean slope shows a decrease (10.20 per cent). Volume development, length of shoreline, and shoreline development also increased. The mean depth of sediment which accumulated during this period was only 9.36 feet, which is less than one third of the average amount that accumulated in the other nine basins during the same time (Table II).

In sharp contrast to the morphometrical changes that occurred during the Algonquin stage every morphometrical feature shows a decrease in value from the beginning of the high-level stage. The average depth of sediment accumulated during this later period is 25.46 feet. Most of it settled in the central deep part of the depression (Fig. 5), which is shown by the facts that there was only a 10-foot elevation in the isolation contour and that the maximum depth decreased 31.75 per cent.

*North Fish-Tail Bay depression.* — Since about the same amount of sediment accumulated around the periphery as in the center, both during the Algonquin stage and subsequently (Fig. 5), North Fish-Tail Bay depression might be taken as the mean of the ten depressions. The justification for this conclusion is found in the morphometrical changes (Table II) that took place during the two periods; they are all negative except volume development and shoreline development, both of which increased between the original and the high-level stages. For example, between the original and the high-level stages the area decreased 31.81 per cent, maximum depth 58.54, mean depth 28.45, volume 73.51, mean slope 60.44, and length of shoreline 9.90. The average depth of the sediment that formed here is 24.18 feet. The corresponding figures for the changes from the high-level to the present stage are considerably greater; they show acceleration in the same trends, which is undoubtedly due to the greater relative quantity of sediment that accumulated during this time, namely, an average of 33.83 feet.

*Stony Point depression.* — This depression formed an arm of Grapevine Point depression during the Algonquin period (Fig. 2) but was cut off as an independent depression as early as the time of the high-level stage by a ridge of sediment that formed across the base of the arm (Fig. 3). During the high-level and the present stages of the lake there has been a fairly uniform accumulation of sediment

over the entire basin, which has reduced moderately the area, maximum depth, mean depth, volume, slope, and volume development (Table II). The length of shoreline and the shoreline development increased slightly. These changes are very much like those that occurred in North Fish-Tail Bay depression during the same period. The average depth of sediment deposited is 13.32 feet.

*Roberts Point depression.* — The striking feature about Roberts Point depression is that between the original and the high-level basins it shows, among all the depressions, the greatest change in elevation of its isolation contour (from 60 to 20 feet), owing to the damming of the basin at the southeastern and northwestern corners rather than to an accumulation of sediment around the periphery (compare Figs. 2-3). These changes caused the greatest relative increase in area in all the depressions (204.66 per cent). This increase was partly because most of Boys Camp depression became incorporated with it by the time the high-level stage had been reached. There was an increase in maximum depth of 20.51 per cent, which is the greatest increase in depth that took place in all the depressions. The fact that the area increased more than the volume and the maximum depth caused decreases in mean depth (12.96 per cent) and mean slope (38.85 per cent). The volume increased by 165 per cent. The volume development decreased 27.27 per cent. This gave the high-level basin the lowest value in volume development (0.8) in all depressions at any stage. Length of shoreline and shoreline development both increased (97.30 and 9.09 per cent). About an average amount of sediment (23 feet at boring 6) settled in the center of the basin during the Algonquin stage.

From the high-level to the present basin every morphometrical feature changed in a manner opposite to that noted above for the changes from the original to the high-level stage (Table II). Fifty-one feet of sediment accumulated during this period at the point where boring 6 was made. That most of the sediment accumulated in the center of the depression during this period is shown also by the lack of any elevation in the isolation contour.

*Sedge Point depression.* — Of all the depressions this one was originally the smallest in area, volume, and length of shoreline, but it was one of the deepest (83 feet maximum depth from the isolation contour). The small area and the great depth account for the unusual steepness of its mean slope (13.49 per cent). It filled rather

slowly around the periphery but rapidly in the center during the Algonquin stage (Fig. 5). The depression increased in area (44.31 per cent) and decreased in maximum depth (44.58 per cent) and mean slope (59.30 per cent). The length of shoreline increased 11.32 per cent. Volume decreased (27.81 per cent), as did volume development (8.33 per cent) and shoreline development (8.33 per cent).

During the high-level and the present stages of Sedge Point depression sediment settled slightly faster around the edges than in the center, since there was a decrease in area of 24.37 per cent and in maximum depth of only 15.22 per cent. These changes caused an increase in mean slope of 19.31 per cent. Volume development increased by 18.18 per cent. Except for volume development between the original and the high-level stages, Sedge Point depression shows the same trends in morphometrical features (but to a less degree) that Bogardus Point depression did at corresponding stages. This is probably because both basins filled in the center faster than around the edges during the Algonquin stage and faster around the edges than in the center during the high-level and the present stages.

### 3. COMPARISON OF THE MORPHOMETRICAL CHANGES IN THE LAKE BASIN CONSIDERED AS A WHOLE

When Douglas Lake is considered as a whole, it is found that its area decreased 13.04 per cent from the Algonquin to the high-level stage and 7.7 per cent from the high-level to the present time. Maximum depth decreased little (3.98 per cent) from the Algonquin to the high-level stage because of the small amount of filling in Fairy Island depression (the deepest place), but maximum depth decreased 53.89 per cent during the high-level and the present stages because Fairy Island depression filled absolutely more than any other depression (104 feet). Mean depth decreased 40.19 per cent during the Algonquin stage and 36.59 per cent subsequently. The decrease in volume was 55.60 and 56.16 per cent; in mean slope, 36.86 and 24.44 per cent. Volume development decreased during the Algonquin stage 28.57 per cent but reversed this trend and increased in the subsequent stage by 20.00 per cent.

These morphometrical data indicate that during the Algonquin period the lake (as a whole) filled around the edges faster than in the deeper parts but filled in the depressions almost exclusively during the high-level and the present stages. Comparison of Figures 1, 2, and 3



(contour maps of the original, high-level, and present stages) and examination of Figures 4 (cross-section profiles) and 5 (graph of areas of contours) will make this generalization evident.

#### 4. BOULDER BELTS

Boulders of considerable size (up to two feet in diameter) are found at several places around the edges of Douglas Lake. Some of them lie on deposits of sand many feet in depth. They were noted near borings 11, 21, 22, 38, 40, 49, 59, 71, 102, and 105 (Fig. 1). The texture of the material that makes up the shore in most localities mentioned is not such as to suggest that the shore is their source.

#### 5. SAND STRATA IN DEPRESSIONS

Fairy Island depression had a layer of washed sand and gravel (up to 5 mm. in diameter) twenty feet in thickness at boring 2 and with an estimated thickness of thirty-five feet at boring 37, which lies between the marl of the warm-water deposit and the pink clay of the Algonquin (cold-water) deposit. Roberts Point depression had an eighteen-foot deposit of washed sand at boring 7 overlying the original bottom.

The depressions mentioned above accumulated very little deposit in their centers during the Algonquin stage and, consequently, their maximum depths were reduced only slightly. They are the basins that had the largest volumes as well as the steepest slopes at the end of the Algonquin stage. These findings make it seem likely that they were occupied longest by blocks of ice.

#### VOLUME OF SEDIMENT AND PERCENTAGE OF FILLING OF BASINS

Table III shows the volumes of sediment of the various basins and the percentage of their filling. With the exception of Roberts Point and South Fish-Tail Bay depressions the absolute volumes of sediment that settled in the original depressions during the Algonquin stage of the lake (original to high-level in the table) were greater than those which accumulated subsequently (high-level to present in the table). The reverse is true, on a percentage basis, for all but Sedge Point depression. More than twice as much sediment settled in the lake as a whole during the first period as subsequently (4,582,776,000 and 2,058,089,000 cubic feet).

TABLE III

\* VOLUMES OF SEDIMENT (IN THOUSANDS OF CUBIC FEET)  
AND PERCENTAGE OF FILLING OF BASINS

| Names of depressions      | Original to high level |                            | High level to present |                            | Original to present |                            |
|---------------------------|------------------------|----------------------------|-----------------------|----------------------------|---------------------|----------------------------|
|                           | Volume of sediment     | Percentage of basin filled | Volume of sediment    | Percentage of basin filled | Volume of sediment  | Percentage of basin filled |
| Fairy Island .....        | 836,101                | 57.08                      | 546,560               | 77.07                      | 1,465,188           | 90.00                      |
| Grapevine Point ..        | 345,135                | 58.69                      | 168,880               | 69.52                      | 456,768             | 86.05                      |
| Maple Point .....         | 180,782                | 78.77                      | 57,615                | 93.90                      | 254,745             | 98.55                      |
| North Fish-Tail Bay ..... | 132,349                | 80.97                      | 55,279                | 96.50                      | 185,185             | 98.93                      |
| Bogardus Point ..         | 252,813                | 86.56                      | 86,256                | 85.54                      | 287,069             | 98.55                      |
| Roberts Point ....        | 128,816                | 30.00                      | 184,432               | 61.35                      | 152,915             | 56.77                      |
| South Fish-Tail Bay ..... | 24,945                 | 12.92                      | 115,119               | 54.73                      | 121,836             | 56.13                      |
| Sedge Point .....         | 56,738                 | 58.25                      | 31,778                | 51.28                      | 78,877              | 72.33                      |
| Stony Point .....         | ...                    | ...                        | 9,657                 | 66.50                      | ...                 | ...                        |
| Boys Camp .....           | 112,248                | 100.00                     | ...                   | ...                        | ...                 | ...                        |
| Lake as a whole           | 4,582,776              | 47.99 *                    | 2,058,089             | 41.44 *                    | 6,640,865           | 69.54 *                    |

\* Exclusive of that part of the basin above the present water level.

The average depth of sediment (Table II) that settled in the various depressions at the several periods shows the differences that have taken place in the rate of sedimentation. Considering the lake as a whole (exclusive of the basin lying above the present water level), the average depth of sediment that accumulated during the Algonquin period was 22.97 feet and that during the periods following, 11.86 feet. Conspicuous differences among the depressions occur between the Algonquin and the subsequent periods. For example, in Fairy Island depression an average of 30.30 feet settled in the first period and 60.30 feet afterward; for Bogardus Point depression the figures are 52.03 and 11.56 feet, respectively. The figures for the other basins range somewhere between these extremes.

Comparison of the average depths of sediment among the various depressions reveals striking differences for corresponding periods. For example, in Fairy Island depression during the high-level and the present periods 60.30 feet was deposited; in Grapevine Point depression, 24.84 feet; in Roberts Point depression, 15.50 feet; and in Sedge Point depression, 13.10 feet. These thicknesses are in great

contrast to those the writer found in the several depressions (much shallower) in Winona and Tippecanoe lakes in Indiana (Wilson, 1936, 1938), where the average depths of sediment were much the same.

Examination of the locations of the depressions in Douglas Lake (Fig. 2) shows that those in the most wind-exposed positions have the least average depth of sediment for the warm-water period; they are Sedge Point, Stony Point, and Roberts Point depressions. Fairy Island depression is in an exposed position and at the same time has the greatest average depth of sediment for the warm-water period (60.30 feet), but it lies at the lee end of the lake. It seems likely that swift currents over the wind-exposed basins do not give time for sediment to settle into them, whereas in Fairy Island depression less swift currents and the possibility that considerable quantities of sediment may be carried ultimately to that part of the lake by return currents could account for the great quantity of sediment that has settled there.

#### DISCUSSION

The foregoing pages have described the diverse types of morphometrical changes that took place in the different depressions of Douglas Lake, the deposition of boulders over deep-sand deposits, the interpolation of sand and gravel layers between the Algonquin and subsequent deposits that occur in some depressions, and the thick deposits of pink clay (Algonquin deposits) around the margins of some depressions where there is scarcely any such deposit in the center. These phenomena can be adequately explained if it is assumed that the great ice blocks that occupied the depressions at the outset of the Algonquin period persisted for varying lengths of time in different depressions and did not disappear in Fairy Island depression until near the close of the Algonquin period. Such a theory implies that, where the ice blocks were thin, as they were around the margins of depressions, in the relatively shallow interdepression zones, and in shallow depressions, they melted early, and such localities became the first repositories of sediment and, therefore, accumulated the deepest deposits of cold-water sediment. Conversely, the deepest and most voluminous basins (at least in their centers) would be expected to become free of ice last and would accumulate the least deposit of cold-water sediment. It would be inferred that, after all

the glacial ice had melted, deposition of sediment would take place according to the distributive factors inherent in the lake as a whole and in the individual depressions.

These expectations are amply verified by the evidence. For example, it has been shown that during the Algonquin stage the very large Fairy Island depression filled almost exclusively around the margin, where the original block of ice was thin and undoubtedly melted early, whereas at the opposite extreme there stand Boys Camp and Bogardus Point depressions (that were originally shallow depressions), in which the ice melted early in the centers of the basins as well as around the edges and became filled almost entirely with pink-clay deposit. In South Fish-Tail Bay depression, which had very steep sides and was deep and well protected by Grapevine Point, its ice block apparently melted very little until late in the Algonquin period and, consequently, the depression has relatively little pink-clay deposit. The other depressions are intermediate between those already discussed.

That ridges on the original bottom of the lake began deposition early because they became free of ice seems well illustrated at boring 4, between Fairy Island and Roberts Point depressions. Here the original depth was only 42 feet (from the surface of the present basin), and there are only 25.5 feet of pink-clay deposit and one-half foot of recently deposited sandy organic matter. A similar example occurs at boring 8, in the interdepression zone, where there is a 42-foot pink-clay deposit that reaches to the base level of wave action and over which only one-half foot of sandy organic matter lies.

According to the general theory presented above, the boulder belts superimposed on sand could be explained by assuming that the sand deposits over which the boulders are lying were made around the margins of the depressions while the ice blocks in the centers of the depressions were anchored to the bottom. It may be assumed that during such a time wave action and currents were adjusting the shoreline and carrying sand into the water near shore. The melting block of ice may have contributed some sand to this zone. Finally, when the ice block in a depression freed itself from the bottom and floated, it may have drifted toward the shore and melted and thus have dropped its boulders on the previously deposited sand.

The presence of the sand and gravel layers interpolated between the cold- and warm-water deposits in the deepest depressions can

be explained in two ways: (1) One might assume that after the ice blocks had melted the increased wave action caused violent shore adjustments in which considerable sand was carried to the center of the depressions, where it settled before the deposition of warm-water sediment began; (2) The ice block could have dropped its burden of sand and gravel directly into the depressions as it melted, after it had become detached from the bottom and was floating.

The place of deposition of sediment during the Algonquin period was controlled to a large extent by the blocks of ice that occupied the depressions and, as has been shown, most of the sediment settled around the periphery of the depressions during that time. During the high-level and the present stages of the lake the controlling factors in distribution of sediment have been those inherent in the shape and form of the basin itself. In these later periods nearly all the sediment has settled in the centers of the depressions and very little around the periphery of the lake. This is what is to be expected in a lake as large as Douglas Lake, the long axis of which lies in the direction of the prevailing winds. That is, wave action is so vigorous that the shore out to the base level of wave action is being eroded and the abraded material is being carried away to settle in the depressions. Undertow and return currents down to the level of the thermocline and currents below that level at the spring and autumnal overturns probably keep the fine sediment suspended until it reaches the depressions, where it can settle to the bottom permanently.

HEIDELBERG COLLEGE  
TIFFIN, OHIO

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# **GEOGRAPHY**





# PHOTOGRAMMETRIC MAPPING AND THE WAR

TALBERT ABRAMS

IN AN interview with the press several years before the Munich incident a high German army officer made the following statement: "The nation that has the best maps will win the war." In view of this statement the odds against the Allies were terrific when the United States entered the war late in 1941. Only one fifth of the land area of the world had been mapped in sufficient detail to make the small-scale charts that the Army Air Forces required if we were to avoid the unnecessary loss of our military aircraft in their operations around the world.

Aerial photography or photographic aviation has grown by tremendous strides, owing to the impetus of war. This science has a history of some eighty years. In this short period of time it has expanded from an aviation hobby to a recognized science and is now officially credited with obtaining 90 per cent of our military intelligence.

The end uses of photographic aviation are the making of mosaic and topographic maps and photographic interpretation. In order to compile a good map the operator should first be able to read one. A map speaks a language, and through the efforts of national cartographic societies the language is fast becoming a universal language.

Map reading was one of the weak points in our army training previous to this war. Many mistakes in maneuvers and installation planning have been traced to the inability of junior officers to orient themselves correctly and to ascertain their position and destination on their maps. To remedy this condition there were set up through-

EDITOR'S NOTE — The reader of this article will doubtless infer, rightly, that the author has been making an important contribution to the war effort. He invented several of the instruments shown in the plates and introduced refinements in others. He developed improved methods of using equipment already available. The company of which he is president has been supplying standardized photogrammetric instruments to our armed services, and telegrams from officers of the United States Fleet operating in the Pacific Ocean attest their value in the conduct of the war.

out the United States training centers or schools in terrestrial and aerial surveying, photographic interpretation, general mapping, and map reading. These schools were conducted by and for all branches of the armed services and were designed to give thorough training in cartography in a minimum of time.

Several of these schools were conducted by private organizations under contract with the armed services. These companies had been practicing aerial mapping for many years. Their experience qualified them as able and efficient instructors for the carefully chosen enlisted personnel the armed services detailed to these schools. This training was planned by the different staffs of the contracting companies in coöperation with ranking marine, military, and naval officers and was outlined to give a review of the fundamentals of mathematics up to and including spherical trigonometry, elements of topographic drafting and surveying, and the basic principles of photogrammetry.

The students in these special training courses consisted of a large group of commissioned officers and enlisted men. They were in attendance ten hours a day six days a week for a period of three months. Upon completion of their course they immediately joined the Pacific Fleet, where their work as mapping units won for them the praise of the Supreme Command in the Southwest Pacific and other theaters of operation. They were first at Guadalcanal, Tulagi, and adjacent islands when we started our invasions of Japanese-held territory.

The first group of students was followed by a second, and then a third. For each group the training became more severe and thorough. As the courses progressed, meetings were held by officers in charge and the instruction staff to suggest ideas and methods, and to stress plans and programs of major importance. The making of photogrammetric engineers for the immediate use of the Army, Navy, and Marine Corps was their main objective. Upon completion of these intensified training courses the members of the various classes were shifted to battle fronts around the world, where they have since played splendid parts in compiling invasion maps of enemy-held territory.

This teaching of a course in photogrammetry with a scope that covered the entire subject material from planning the photographic mission or flight to compilation of the finished map was an event unique in the history of the science. There were no precedents to

serve as a guide, nor were there any standard types of photogrammetric instruments. Under the stress of war research work was instituted on newer and faster methods of utilizing aerial photographs by the Army Air Forces, Navy Bureau of Aeronautics, and the Corps of Engineers. By 1942 much of the research had crystallized with suggestions incorporated into a standard practice, but the need for this type of precision equipment had far outgrown the supply. Although photographic aviation has a historical background of eighty-one years, the first fifty years was a period of research in processes, cameras, lens, filters, and paper.

So far as is known, the earliest aerial photograph for military purposes was taken in 1861 by the Balloon Corps of the United States Army with the camera installed in a special-type kite. The airplane was first used as a medium for transporting the camera in 1909, when Wilbur Wright conducted experiments on the feasibility of using heavier-than-air craft for photographic work. The achievement was followed by many others, of course, but practical aerial photography dates from the early days of World War I, and even then its adoption as a regular military accessory met with much skepticism in high circles.

After being shown aerial photographs of enemy territory, the Allied Command became intensely interested, and vigorous efforts were started to acquire equipment and to formulate methods of procedure. No aerial cameras were available, so that hand-held ground cameras with glass plates were used, but research was instituted immediately on this type of instrument and soon special types were developed.

In the early years of aerial photography all cameras were operated manually from different parts of the plane. The British held their cameras over the sides of the cockpit, while the French suspended theirs through holes in the floors of their planes. Photographic information of enemy territory had proved so valuable in a few months that in the Meuse-Argonne offensive some 60,000 prints were supplied the American forces in just a few days. No attempt was made at that time to utilize the pictures for anything but individual photographic interpretation, although in some cases overlapping photographs were mounted on a card and studied by means of the hand-held stereoscope that was standard parlor equipment at that time.

Despite this research on equipment and methods, it is generally known that Germany and Italy had accomplished far more along the same lines, but as history shows, other combatants were making great strides in the same direction. The introduction of aerial photography materially changed the conduct of the war so far as hiding troop movements and camouflaging installations were concerned.

The period following World War I and extending up to the beginning of the present conflict saw a slow, steady growth of the practical application of photogrammetry to peacetime pursuits, developments, and explorations. At the same time, because it was considered a definite part of any peacetime military program, the armed services continued their training schools, though on a reduced scale with a moderate research and testing program.

The value of stereoscopy and stereoscopic models for interpretation work had been realized for some time prior to 1925, but to obtain prints suitable for use with a stereoscope required the proper amount of overlap of the pictures along the line of flight. The problem of achieving this overlap taxed the camera man and often resulted in taking more pictures than were required or in making a reflight because of insufficient coverage.

Researchers began working on devices to control the interval between pictures automatically and developed what is known as the "intervalometer." With the aid of a view finder, ground-speed indicators, or optical sights the interval required between pictures to give the proper overlap can be determined, and a proper setting of the intervalometer will control the automatic or mechanical operation of the camera, and thus regulate the distance between pictures or their running overlap.

Today's intervalometer (Pl. I, Fig. 1) has completely outgrown its initial crude design, capable of performing only one job, and is a precision instrument with many modes of control. The latest type which is being procured by the Army Air Forces can be used on four different kinds of timing operations. This instrument plays such an important part in helping to record the results of a reconnaissance or bombing mission that its operation is coördinated with that of the bombsight.

Better control of the interval between pictures naturally created a wider use of stereoscopic pairs of photographs, and hence a desire for a more practical and efficient stereoscope. The stereoscope it-

self has changed materially from the old hand-held instrument to the large mirror magnifying model, to the smaller binocular type, and then to the magnifying lens stereoscope with the adjustable interpupillary distance and folding legs. This CF-8 type (Pl. I, Fig. 2), which just fits the soldier's pocket, is found in all theaters of operation wherever photographic interpretation is carried on.

The application of aerial photography to peacetime operations created a desire for a composite map or for some method by which many adjacent photographs could be used together, either glued or stapled down to a flat surface. A method of procedure was devised whereby overlapping photographs could be superimposed one on another and matched detail to detail. Any print displacement of ground objects caused by tip or tilt of the plane made the matching of detail a difficult task for the area around the edges of the print. This area can easily be trimmed off the print by cutting completely around the picture with a razor blade, leaving only the center portion, where the scale is more accurate. The center is used in making the composite. The adhesives are gum arabic, mucilage, paste, or rubber cement.

Mosaics are typed according to the degree of accuracy of the finished product. The uncontrolled mosaic in which no means are available for orienting the prints with respect to one another and which is satisfactory where the relative location of detail only is required is the least accurate. The semicontrolled mosaic is made up from photographs upon which a small amount of measured control has been established. This type is somewhat more accurate than the uncontrolled. This measured control exerts its influence on accuracy of the mosaic by forcing the mapper to pay close attention to the expansion and contraction of the prints. The most accurate is the rigidly controlled mosaic, which is constructed on a network of points plotted on a base by means of their absolute coordinates.

Owing to their overall representation of the included area, mosaics have come to be used universally as map substitutes. In peacetime they give to the city and highway engineers, council chamber, real-estate development company, and mineral and petroleum prospectors a composite picture with detail delineated with 100 per cent accuracy. In military usage a mosaic presents to the intelligence officers a bird's-eye view not only of their own positions but also of

those of the enemy. With directions and scale accurately shown, they can even be used for artillery purposes.

Photogrammetry could never attain the status of a mapping method unless it included some means of determining elevations or interpreting contours from the photographs themselves. The evident height as shown in the third dimension of the spatial model is only a quantitative one. From the science of physics it was known that there is an evident parallax or horizontal displacement of points in a photograph due to elevational differences. The problem was simply that of devising a way to measure this horizontal displacement. By means of a contour-finding instrument (Pl. II, Fig. 1) it is now possible to make this measurement. The measuring unit of this equipment consists of several precision gages graduated in millimeters and two small pieces of plexiglass. These plexiglass parts have a very small red dot approximately at their center and are about two and one-half inches apart in a horizontal direction. By placing the instrument over a pair of prints having the proper amount of overlap existing between them it is possible stereoscopically to fuse these two dots at any predetermined elevation of the ground shown in the prints, and when the instrument is moved to another part of the print where the ground is of a different elevation, the two dots separate. The particular amount they must be moved to be fused again is a measure of the difference of elevation between the two settings of the instrument on the prints and is proportional to the altitude of the photographic plane, focal length of camera, and the distance between principal points of the photographs.

Thus the contour finder was developed, and it has proved a boon to the science of photogrammetry. We are now able to fly a mission and to produce a finished contour map. If the size of the project permits, we can interpret contour lines in one tenth the time required by field-surveying methods. The military soon adopted this instrument and used it to a great extent in mapping their more permanent bases and laying out improvements. Speed is the by-word in all military movements, and this method of contouring satisfied the demands of the armed services.

It can readily be understood that aerial mapping and ground surveying are very closely interrelated. In order to tie an aerial survey accurately to its correct ground position, a few points

whose absolute coördinates are known must be established on the ground in the area of the survey and be identifiable in the photographs. These ground points are located by surveying methods, and if they were to appear on each photograph their exact location in the field would require an enormous amount of precise surveying. The object of aerial mapping is to eliminate unnecessary field-control work. By making use of the old geometric principle that three lines must intersect to locate a point engineers are now able to space their ground control from fifteen to twenty prints apart. Construction of mechanical triangulator templates built up on carefully selected picture points (Pl. II, Fig. 2) makes it possible to extend the rigid control exerted on the flight by any one survey point over the intervening prints to the next survey point.

Of the inherent errors present in aerial photography, tip and tilt resulting from natural flying conditions present the greatest obstacle to accurate mapping. This has been partially overcome by the use of the automatic camera mount (Pl. III, Fig. 1), which is so actuated by a photoelectric cell as to correct instantly the position of the camera for any deviation of the plane from a straight and level flight. Distortion in detail caused by tip and tilt occasions much extra work when transferring planimetry from the prints to the map base sheet.

Let us consider for a minute the problem of adjustment when attempting to make a map to a scale 1 inch = 800 feet with prints ranging in scale from 1 inch = 790 feet to 1 inch = 810 feet. One might ask, "Why this difference in scale?" It is possible to compute the height necessary to fly to produce any desired print scale. Because of flying conditions and changes in elevation of the terrain, however, it is difficult to maintain this height. In mountainous country the plane would have to fly at many different heights to obtain the same scale for each print. It would be impossible to do this. The practical procedure is to fly at as uniform a height as possible and to secure an overall scale of prints as close to that desired as feasible, and then to use a vertical sketchmaster (Pl. III, Fig. 2) to correct for scale errors or variations in each print. The vertical sketchmaster is an instrument with adjustable legs, a front-surface reflecting mirror, and a half-silvered mirror and is used to transfer the print detail to the base sheet. Basically, it is similar to an epidiastroscope and prints of a size nine inches square can be used



in it. By means of the adjustable legs a print, when inserted in the vertical sketchmaster, can be so oriented as to correct for tip, tilt, and scale distortion and thus be put in the same position the negative was when the picture was taken. When the detail is projected down to the base sheet it is in the correct scale of the desired map (Pl. III, Fig. 2).

In the early part of 1941 conditions in the Pacific apparently were tranquil, but to some people this peacefulness forecast a coming storm. We should thank certain of our military personnel who were awake to conditions and saw the necessity of having available some permanent lines of communication with our outposts in Alaska and the Aleutians. As a result of such thinking the Alcan Highway project was developed.

It was realized that this project might require an immense amount of ground surveying and an even greater amount of vertical aerial photography. Speed was essential, and ordinary methods would not suffice. After much deliberation a procedure for mapping this territory from the air was worked out combining oblique aerial photography, which is the accepted practice in Canada, and vertical aerial photography, up to this time the standard method for aerial surveying in the United States. Since three cameras are used in accomplishing the photography the method is officially called the "trimetrogon system."

The three cameras are synchronized, one being aimed vertically downward, the other two at a sixty-degree angle to the vertical at right angles to the line of flight. Three pictures are taken at one time, with resulting photographic coverage from horizon to horizon. This great coverage makes it possible to have the flight lines fifteen or twenty miles apart, instead of the customary one to three miles.

By skillful use of trimetrogon charting methods the United States was able in the time interval between spring and December 7, 1941, to photograph upwards of 500,000 square miles. The results of this survey speeded location work on the Alcan Highway, and a completely American method solved the problem of a continuous and uninterrupted line of communication with our outposts.

In the beginning trimetrogon was a charting system, but with the aid of research such scientific equipment as the rectoblique plotter (Pl. IV, Fig. 1) for making distances and directions on oblique prints compatible with those on the vertical, the oblique sketch-

master (Pl. IV, Fig. 2), which handles oblique prints as the vertical sketchmaster does the vertical prints, and the long-armed mechanical triangulators are fast changing it to a precision mapping system.

Briefly summarizing photogrammetric mapping and its war applications, we shall go back to the First International Congress of Photogrammetry, which was held in Rome, Italy, in 1938. It was the author's privilege to attend that congress as a representative of the American Society of Photogrammetry. Germany had moved into and occupied Czechoslovakia, and World War II was on its way. Instrument makers in Europe were developing and manufacturing many pieces of scientific equipment for photogrammetry, but all were ostensibly for making precision surveys in areas already well mapped. Our thinking in the United States was much different. We needed charts for aerial navigation and maps of large areas that were to be mapped for the first time. No charts were available for the new network of aerial routes the War and Navy departments were planning in order to extend the activity of their air arms to all possible battle fronts.

One of the first moves at the outbreak of this war was to organize the Map and Chart Division of the United States Army Air Forces, which absorbed the existing civil mapping agencies. The Lambert Conformal method of projecting the spherical surface of the earth to a plane surface was accepted as the basis for the new aeronautical charts.

Available camera equipment was consolidated into the trimetron system, and the four instruments, namely, the vertical sketchmaster, oblique sketchmaster, rectoblique plotter, and mechanical triangulator were selected as the general type of equipment to be used in the map compilation from the horizon to horizon pictures.

Ground surveyors trained in the use of astrolabe equipment proceeded into the wilds of unexplored countries to get the geodetic control necessary to chart the rapidly expanding routes that were being planned to cover the world. The entire program is now rapidly advancing, and the trend of the present conflict gives evidence that it was justified.

On the battle fronts pictures are being used by the million to map and study enemy-held territory before every advance. Stereoscopes, contour finders, and pictures are being issued to small military groups on many occasions, and photographic interpretation

units have developed a science all their own as a part of military intelligence.

In the last war aerial photography was a by-product of an observation squadron, whereas in this war complete wings of the Army Air Forces are devoted to aerial photography in all its ramifications, and special squadrons for trimetrogon mapping reconnaissance, bomb recording, military intelligence, and training instruction are organized to expedite the war.

The future of aerial mapping is very promising. The entire world is still inadequately mapped for peacetime international planning. At present, only maps for military purposes are being stressed. Reconstruction periods, which follow every chaotic era such as this, will demand maps of all kinds. The huge development programs, boundary surveys, and the like will require maps of various degrees of accuracy. The world is now map-conscious, and we shall see huge mapping projects of entire nations and continents being carried out. By using ordinary ground surveying these projects would be improbable, if not impossible, whereas photographic aviation and photogrammetry can be used to accomplish them in a comparatively short time.

ABRAMS INSTRUMENT COMPANY  
LANSING, MICHIGAN



FIG. 1. The intervalometer, an automatic electric timer, with four modes of operation



FIG. 2. A military student studying photographic interpretation with the stereoscope





FIG. 1. An operator tracing contours with the contour finder



FIG. 2. Complete network of control built up with lazy-daisy  
mechanical triangulators



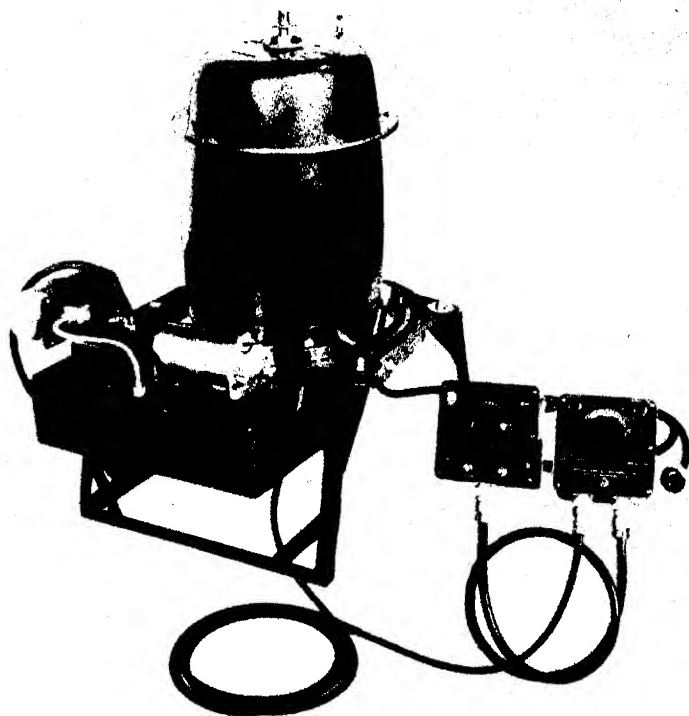


FIG. 1. Automatic camera mount



FIG. 2. An operator tracing planimetry from a vertical print  
with the vertical sketchmaster





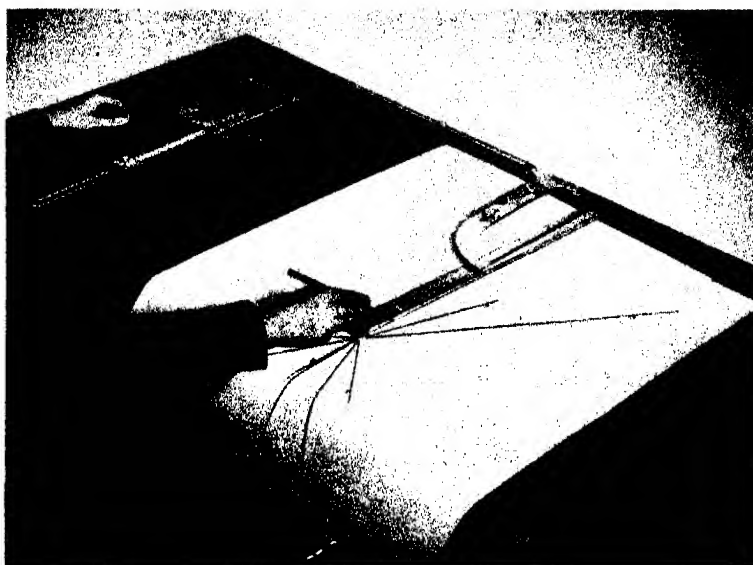


FIG. 1. Rectoblque plotter board used to project distances and direction from trimetrogon oblique prints to the same plane as the accompanying vertical print



FIG. 1. Tracing planimetry from an oblique print on a base sheet with the oblique sketchmaster



# A SURVEY OF RUBBER ON THE MIDDLE MARAÑÓN, PERU

HARRY E. HOY

BY THE end of 1941 events in the southwest Pacific had brought the United States face to face with an acute rubber shortage. Frantic attempts were made to find both natural and synthetic substitutes, as well as new sources of this strategic war material. It was inevitable that attention should again be focused on the vast potential supply of natural rubber in the extensive forests of the Amazon Basin. This paper deals with a survey of a stand of rubber trees in one small area, that of the middle Marañón in Peru (Fig. 1).

Tree rubber is produced in the tropics between 10° N. and 10° S. Situated at approximately 5° S., the middle Marañón has nearly all the physical conditions favorable for the growth of rubber. Among them are the high temperature, with a mean of 78° to 80° F.; the heavy rainfall throughout most of the year; and the fertility of the soils, which is relatively good owing to the ridge-and-valley character of the land. The altitude, ranging from 600 to 2,500 feet, is high, though still within the natural limits of rubber trees. The latex of *Hevea guayensis*, the species native to the region, is of excellent quality, although *Hevea brasiliensis* has a greater yield. The trees grow on slopes that are free of lianas, but are rarely found on the valley floors, which are flooded during part of the year.

An indication of the density of the stand of rubber trees in the middle Marañón, probably the densest in the Amazon Basin, is the count of 965 trees in thirteen sample traverses. The average diameter of trees is 13 inches, and the average distance between them is 75 feet. It is estimated that in the area within twenty miles of the traverses there are sufficient trees to warrant two thousand *estradas* ("trails"). Ordinarily an *estrada* is cut through the forest so that the tapper may reach from seventy-five to a hundred rubber trees.

## DIFFICULTIES OF EXPLOITATION

The middle Río Marañón differs from the upper and the lower sections in that it is inaccessible either by land from the west coast

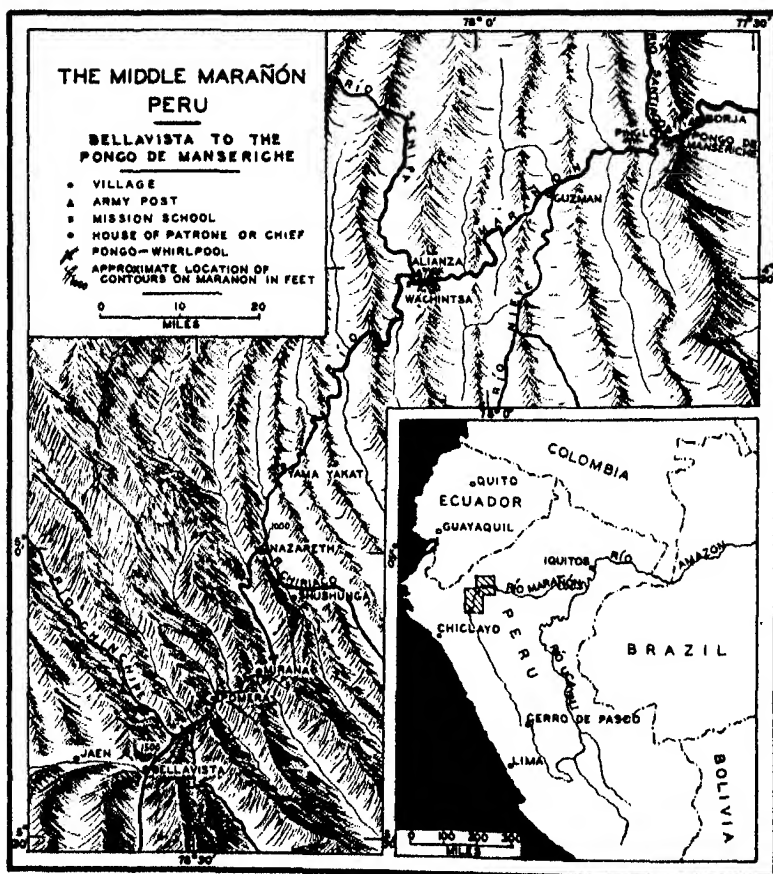


FIG. 1. Surface configuration of the middle Marañón Valley

or by water from the Atlantic. The present mule trail across the Andes to Bellavista, the easternmost settlement maintaining regular contact with the desert oases of the Pacific coast, is being replaced by an all-weather automobile road. River launches maintain regular service upriver to Borja on the lower Marañón at the Pongo de Manseriche, but between Bellavista and Borja it is almost impossible to go upstream on the Marañón, and it is quite dangerous to travel downstream because of the *pongos* ("whirlpools and rapids"). There are no continuous land trails across the region.



FIG. 2. View down the Río Marañón in the more rugged section of its valley above the mouth of the Río Senipa

The surface features of the region are dominated by the parallel system of north and south ranges which are the eastern foothills of the Andes. Exact altitudes of the ranges, of which the westernmost is the highest, are not known, but they probably vary from 9,000 to 1,500 feet. The easternmost, through which the Marañón flows in the Pongo de Manseriche, is higher than any one of several ranges immediately to the west. Practically all the surface is in steep slopes, many of which are of  $45^{\circ}$  (Fig. 2). The steepest one measured  $60^{\circ}$ , but steepness of slope has not prevented the growth of a forest cover. In the eastern part of the region the valleys are wider, in contrast to those west of Alianza, where there are very narrow flood plains (Fig. 3); to the east of this place they range from one quarter to one mile in width (Fig. 4).

A rectangular or trellis pattern of drainage has evolved (Fig. 3), with the general trend of the streams north and south, parallel to the ranges. The Marañón receives most of its tributaries at points immediately upstream from the water gaps.

Crystalline rocks are exposed along the river where it cuts through the westernmost ranges. Farther east sandstone, shale, limestone, and conglomerate compose the strata of the ranges.

The climate of the region may be characterized as Tropical Rainy. Although there are no weather records available, interviews with



FIG. 3. The junction of the Marañón and Chiriaco rivers. A trellis pattern of drainage has evolved in the ridge-and-valley arrangement of the Andean foothills



FIG. 4. The water gap of the Pongo de Manseriche from the southwest. The Marañón in the foreground is backed up by the floodwaters of the Río Santiago entering from the left foreground

natives indicate a climatic condition quite similar to that of the region farther east in Peru.

The season of heaviest rainfall is in March, April, and May. The

dry season includes July, August, and September. Apparently the month of August during some years is practically rainless. During May of 1943 rain fell each night and on half the days, but there seemed to be no regularity in the time that the rain fell. The rainfall in May was of two types: (1) convectional showers in heavy downpours of short duration, and (2) tropical cyclonic storms with low, dark stratus clouds. Rains of the latter type were more gentle and often continued for thirty-six to seventy-two hours. That the windward or eastern slopes have a more luxuriant cover of forest than the western slopes indicates an orographic factor in the distribution of rainfall.

The noncyclonic rains are usually local, and the rivers rise and fall rapidly. On May 13, when local rains in the drainage basins of the Senipa and Santiago rivers caused them to rise twenty feet in twenty-four hours, their flood waters backed up the Marañón for six miles.

Temperature in May ranged from 73° F. at sunrise to 86° F. at midday. According to natives, temperatures differ but little from month to month, and the sun is obscured by clouds at least a part of each day. The relative humidity is very high, but breezes may relieve the otherwise high sensible temperatures. Where winds are obstructed by mountains or forests, the oppressive heat makes strenuous work difficult. Settlements are usually established where there is an exposure to east winds, and locations at or near the east and west gorges are pleasant because the fresh breezes blowing there bring relief from insects and high humidity.

The greatest handicap to the full utilization of the rubber resources of the region is lack of labor. There are perhaps one thousand families of Aguaruna Indians in the region; in addition, there may well be fifty Peruvian families (Fig. 5). Exact population figures are not obtainable. The Aguarunas are relatives of the Jíberos tribes (Fig. 6), but they do not shrink heads, a practice no longer widespread, as do their relatives on the upper Napo and Putumayo rivers.

The sparse population uses but a negligible part of the land for crop production. The clearings are small, and only two as large as an acre were seen (Fig. 7). The Indians, who have little need for money, are almost entirely self-subsistent. Their basic food requirements are supplied by a patch of yuca or manioc, a starchy diet that is supplemented by fish and wild birds. Most families have a number





FIG. 5. A group of Aguaruna Indians with a variety of styles of dress and weapons. The weapons are the machete, blowgun, javelin, bow, rifle, and muzzle-loading shotgun

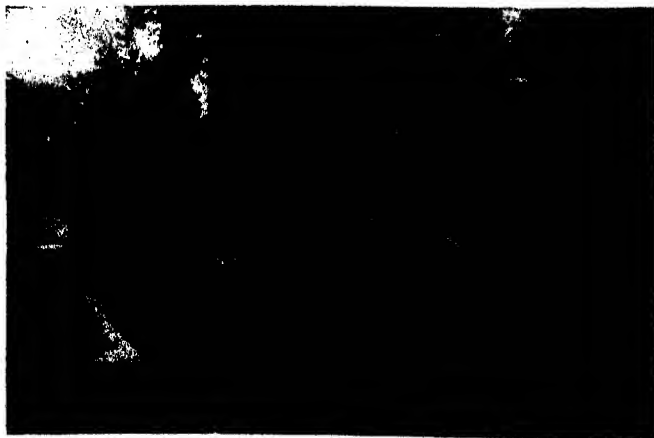


FIG. 6. Five Indians (wearing turbans) equipped with blowguns and poison-tipped darts with which they hunt birds

of scrawny chickens. A few raise bananas, peanuts, pineapples, papayas, or sweet potatoes (Fig. 8).

The stream gravels, which contain gold, have furnished the only

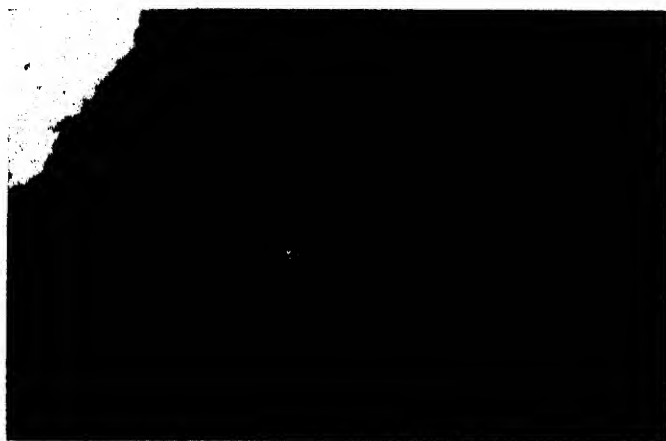


FIG. 7. A small clearing around an Indian's hut (shown in Figure 9 also). The Río Marañón is at the upper left-hand corner



FIG. 8. Adventist mission at Yama Yakat. The Río Marañón is in the middle ground; a low range is in the background. View toward the southeast

incentive for commercial activity, and they are panned during the low-water period from June to December. The average output per day is about one gram, for which the miners receive the equivalent



FIG. 9. Aguaruna porters with loads on back supported by a strap across the head. The thirty-five foot thatched hut is shown from above in Figure 7



FIG. 10. Anduashe Cumbia, a superior Aguaruna Indian. He is in line to be chief of the tribe

of five *soles* (77¢) in merchandise. Their most cherished possessions are guns, powder and shot, shirts, pants, tobacco, machetes, and cotton cloth (Fig. 5). At the time of our visit it was questionable

how well rubber tapping, with its more confining routine, would compete with gold panning for the local labor supply. It is unlikely that an Indian can tap more than 77¢ worth of rubber per day. Previous experience with the Aguarunas would indicate that there is little hope of securing more than seventy-five to ninety days of work in a year.

Given the same diet, the Indian seems to have better health than the mixed races. Fevers are not common, although a few cases of malaria were noted. The most frequent ailments are infections of the skin and eyes and diseases caused by internal parasites. These do not completely disable the people, but they greatly reduce their efficiency.

The strength and endurance of the Indians are surprisingly great. We were amazed to see their ability to carry a heavy load all day after consuming nothing but boiled yuca and a drink made from fermented yuca (Fig. 9). Their arms and shoulders are better developed than their legs because much of their active life is spent in battling currents of the swift river in their dugout canoes (Fig. 10).

The region is covered with tropical forests. The western slopes (Fig. 11) near Bellavista have a scrub-forest cover; the rest have a rain forest. There is a very large number of species of trees, and the associations are dependent upon soil, slope, and drainage conditions. The areas subject to overflow for long periods are covered with palms. The *Hevea guayensis* trees are confined to the lower slopes above the



FIG. 11. Cactus scrub forest on an alkali terrace on the west side of the Río Chinchipe. The high ranges to the east reduce the amount of rainfall received here

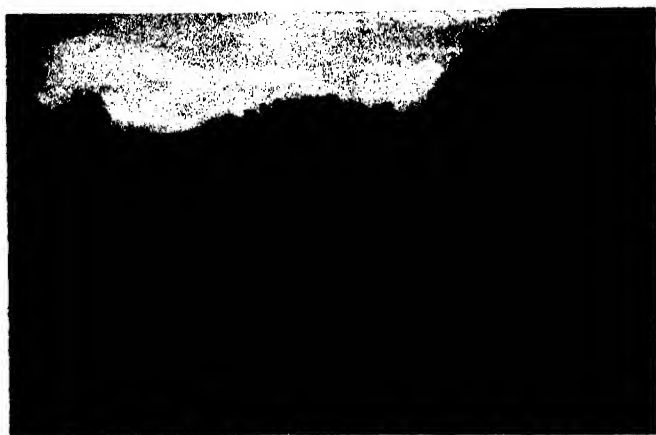


FIG. 12. Río Chiriaco. Rubber trees are growing on the slopes bordering the river. View downstream toward the north

high-water level (Fig. 12). These trees do not grow on flood plains, as does *Hevea brasiliensis*. From above the forest presents a mosaic of greens; the different species may be distinguished by noting the varying shades of green or degrees of dormancy. The forest canopy has the appearance of a vast sea of open umbrellas (Fig. 7).

The floor of the forest, considering only the vegetation, is relatively easy to walk upon. It is the steepness of the wet and slippery slopes in this region that causes the chief difficulty in tapping the rubber.

Hevea rubber falls into two grades, fine and weak. The price of the weak (*jefe debil*), produced by the middle Marañón, is a few cents a pound less than the fine.

The middle Marañón has been a disputed territory during most of its occupancy. Peru has always considered both sides of the river part of her national territory, whereas Ecuador claimed all territory north of the river. The Indians have been but slightly aware of the controversy. They have been interested only so far as the Peruvian army posts scattered through the region have interfered with their way of life. The Rio de Janeiro Conference of 1942 settled the dispute to Peru's advantage, pushing the border well north of the Marañón and near to the eastern flank of the Andes. The influence from outside the region has always been Peruvian.

#### PRODUCTION

Nearly all the middle Marañón is included in one huge concession owned by a Lima corporation, which made plans to exploit the rubber by bringing labor from the mountains. To facilitate the importation of food and equipment a mule trail was started from Bellavista with the idea of completing it to Nazareth, where a landing strip was to be cleared from which rubber would be flown west to Chiclayo and supplies brought back. The almost complete lack of food in the region as well as the time necessary to get production started was responsible for the discouragement of this ambitious project. The imported laborers would have been out of their accustomed environment, and also at the end of a very tenuous supply line.

Instead of carrying out the original plan, the two mission schools in the region have now been organized into tapping centers. That of Yama Yakat, with a student body of twenty-eight, is administered by a Peruvian for boys representing many families, all within a radius of fifteen or twenty miles. An American missionary, Pastor Roger Winans, is in charge at Wachintsa (Fig. 13), where the student body is slightly larger. The boys, who are taught in both the Spanish and the Aguaruna languages, receive practical training in agriculture, handicraft, and sanitation. During Pastor Winans' twenty-five years on the Marañón he became acquainted with most of the Indians and has now organized a number of supervisors, who had contracted with nearly seven hundred Indians to tap rubber by the end of 1943.

There are many advantages in using Indians as tappers. They

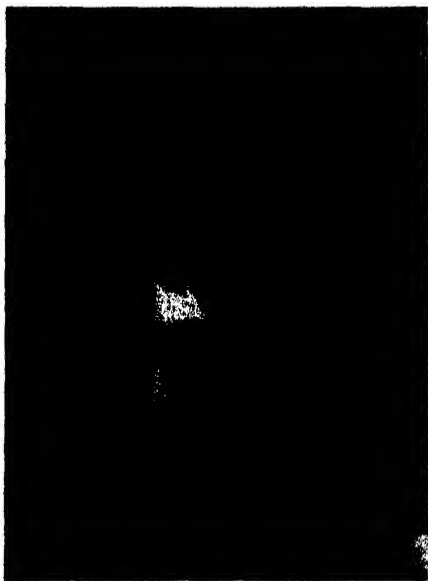


FIG. 13. Pastor and Mrs. Winans on the front steps of their house at Wachintsa



FIG. 14. Simple thatched-roof house without sides on an island below Alianza. A small clearing for yuca and bananas surrounds the hut

are accustomed to raising their own food (Fig. 14), and they may build their estradas near their homes, in which case migration is reduced to a minimum. They are intimately acquainted with their own area and, of course, are adjusted to the environment. It would be almost impossible to use both Indians and imported labor in the same region since the Indians, because of their greater number, would be able to compete with outsiders only through bloodshed. As a result of grievances in 1908 they killed all the white men in the Chiriaco area. Even the importation of three or four hundred mountain people would have meant the loss of a still larger number of Indian tappers, who would either have resisted the newcomers or have retreated into less accessible areas.

The Indian tappers, who are only partially supervised, remain in the area near their homes. Their tapping knives, cups, spouts, buckets, and pans are charged against their future deliveries. The number of machetes, shotguns, and cartridges is strictly rationed. Those who produce the most receive the largest allotment of these coveted articles.

An experienced rubber man lays out the estradas. He is able to detect rubber trees as far as he can see them. An estrada should reach the largest number of trees by the shortest possible route.

Two estradas are cut for each tapper, since an estrada is tapped every other day. The tapper begins his work before daylight, the time when latex flows most rapidly. After the tapping panel has been laid out on each tree, it takes from two to three hours to make the rounds of one estrada. By that time the flow of latex has stopped, and the tubes have sealed themselves. Then the tapper makes a second round with buckets to collect the latex from the cups. Later in the day the latex is coagulated on a paddle over a smoky fire. Chemical coagulation is not being used in the middle Marañón because of the difficulty of importing the acids and lack of experience in their use. Since none of the present tappers have worked with rubber, the use of the *jebong* knife is being taught. This knife, developed on the plantations of the Far East, makes possible the perpetual tapping of a tree. In other parts of the Amazon where intermittent tapping has been carried on, resistance to change from a machete or Amazon knife is encountered.

An Indian's equipment is simple, and his wants are few. His house has a thatch roof of woven palm fronds. If there are no walls, the roof extends to within two or three feet of the ground on at least two sides. Many houses with bamboo walls are thirty-five to forty feet long and twenty-five feet wide (Fig. 15). Where possible, the



FIG. 15. A single hut constituting Pomerá. The man in the black wool coat is suffering from malarial chills. View toward the east





FIG. 16. A balsa or raft made of balsa-wood logs. A platform is built up at one end to keep the cargo dry. Rafts are used for moving all commodities downstream. It is impossible to bring more than a light canoe upstream

homes are located on terraces just above the flood level and so need no floor. The Indians living on the flood plains of the wider valleys near the Pongo de Manseriche build their houses on platforms resting on poles from three to eight feet tall.

The usual dress for men is a wide sarong extending from the hip to the knee. They are eager to obtain shirts and pants, as a few have done. The women wear much more cloth, which drapes from one shoulder and extends nearly to the ground on one side. It will be the availability of these articles, together with guns, machetes, and cigarettes, that will determine whether or not many of the Indians agree to tap rubber.

The rubber from the middle Marañón will have to move down the river in canoes or rafts as far as Borja (Fig. 16), from which launches will take it to Iquitos. At Borja the river, because of its narrowness and meandering character, does not provide a safe landing place for large flying boats such as the Catalinas. Therefore Peru's allotment of rubber, which is transported by plane, will have to be loaded at Iquitos, to be flown over the Andes, and the remainder will move down river to Manaus or Belém for shipment to the United States.

THE OUTLOOK FOR THE MIDDLE MARAÑÓN

Until 1946, at least, the outlook for the middle Marañón as a producer of rubber is fairly bright. Guarantees by the United States will maintain the present high price until that date. It is doubtful whether the region will thereafter be able to compete with more efficient production.

A hasty inventory of the region's resources indicates some of the possible future developments. The forests are the most obvious resource. Rubber trees, though small, are only one fourth or one fifth as far apart as the average for the Amazon Basin. There are many species suitable for lumber, but their smaller size and the greater distance to markets by way of the Amazon preclude exploitation at present. Rafts of logs could be taken through the Pongo de Manseriche during part of the year.

Soils are reasonably fertile, for the level valley bottoms are filled with recent alluvium, but their use is hindered somewhat by periods of flood. The slopes are steep enough for normal erosion to keep pace with leaching and laterization. Most of the food is produced on terrace remnants which are moderately leached. Thus there is no reason why the middle Marañón should be a food-deficit area since nearly all the surface is potentially productive.

Salt outcrops in two sandstone exposures. It has few commercial possibilities, but in this hot, humid land it is of vital importance to the natives.

Reconnaissance surveys for oil have been made, though there has been no drilling. One tributary of the Marañón above the mouth of the Senipa is covered with an oily scum. Natives say that the seeps can be skimmed and burned in lanterns. The area is certainly a potential source of petroleum.

Under present conditions there is little to tempt immigrants. Most of the region is more easily reached from the east than from the west, and any surplus production, with the possible exception of gold, must be sent downstream. The east is the direction of competition for markets and for supplies. Rubber tapping and barbasco planting are today the two most profitable enterprises in the Peruvian Amazon east of the Pongo de Manseriche. The middle Marañón has a late start.

The mule trail under construction from Bellavista to Nazareth

\*and the blasting of rocks to eliminate whirlpools at some pongos are feeble attempts to remove factors of inaccessibility.

An all-weather road to Bellavista connecting with the Pan-American Highway at Piura is under construction. This road crosses the Andes at 6,990 feet in the lowest pass between northern Colombia and southern Middle Chile, and long-range plans call for its extension to Borja. Such a road would reorient and place the middle Marañón in the most favored position of Peru's *montaña*.

Exploratory work has been done for an ambitious railroad and irrigation project which, if carried through, would improve the position of the middle Marañón enormously. Enthusiasts declare that an eight-mile tunnel through the continental divide at an elevation of slightly over two thousand feet would reach the valley of the Huancabamba River, a tributary of the Marañón. By diverting the waters of the Huancabamba through the combination railroad tunnel and aqueduct the largest area of level desert in western Peru could be made productive. The income from water rights is supposed to make the initial railroad venture possible. The railroad would follow the Huancabamba downstream and cross the Marañón south of Bellavista. It could then follow the south bank to Nazareth and be extended southeastward to Moyabamba and the oil fields in the Department of San Martín. Such a venture should open a market on the treeless but occupied desert coast for all types of tropical forest products from the middle Marañón.

MICHIGAN STATE NORMAL COLLEGE  
YPSILANTI, MICHIGAN

# THE ORIGIN OF THE GUMBOTILS OF THE UPPER MISSISSIPPI VALLEY

WILLIAM HERBERT HOBBS

**S**TUDY of the periglacial area of the Greenland continental glacier has shown that, where this glacier is bordered by outwash, the outward-blowing winds of the glacial anticyclone have lifted sand, silt, and clay of the glaciofluvial deposits and dropped them over an extramarginal area. This extramarginal area was not reached by floods on the plains, and in consequence a tundra flora could take root and retain the dust deposits. The coarser sand is usually separated from the silt (loess), but pebbles as much as an inch in diameter are sometimes carried into the loess deposits by saltation.<sup>1</sup>

These effects are brought about by the contrasted processes which obtain during the summer and winter seasons. In the summer the thaw water from the glacier front builds up the outwash plain of gravel, sand, silt, and clay, with many stranded boulders; while during the next winter, when the plain has dried up, it becomes a deflation area over which silt, sand, and small pebbles are lifted by the outward-blowing storm winds and leave behind a pebble pavement — an armored surface which protects the underlying layers from the wind. The stranded boulders are at this time drilled by the sandblast so as to leave harder layers in relief on those boulders which are of heterogeneous composition, and to produce faceted ventifacts out of boulders and pebbles of more uniform or finer-textured rock.

In each succeeding summer the stranded boulders are pushed about, rotated, and overturned by the floating ice blocks and the

<sup>1</sup> Hobbs, Wm. H., "Loess, Pebble Bands, and Boulders from Glacial Outwash of the Greenland Continental Glacier," *Journ. Geol.*, 39: 331-335. 1931. *Idem*, "The Origin of the Loess Associated with Continental Glaciation Based upon Studies in Greenland," *Compt. rend. Congrès internat. géog.* (Paris, 1931), II: 1-4. *Idem*, "Winds — the Dominant Transportation Agent within Extramarginal Zones to Continental Glaciers," *Journ. Geol.*, 50: 556-559. 1942.

swirling currents about them. With each ensuing winter they therefore expose new faces to the sandblast, and so tend to assume an ellipsoidal form — they are never "one-sided."

The loess is laid down only outside the range of the floods of the outwash, since these inhibit the growth of the tundra grasses. The loess deposit is thickest just outside the flooded area, and it thins out with distance from this border.

If the glacier front retreats, the flooded area draws in its margins, and the grasses encroach upon the plain and the loess deposits there. Thus a thin deposit of loess now begins to form over the plain itself, thinning out in the direction of the retiring glacier front (Fig. 1).

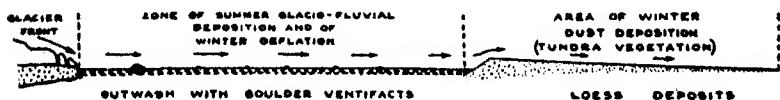


FIG. 1. Glacier front zone of deflation, loess deposits and, later, thin loess layer encroaching on the outwash as the glacier front retires (latest deposit not represented)

The conditions described above obtain wherever glaciofluvial deposits are laid down off the front of a continental glacier, though not *where the surface melting of the glacier remains above the bottom layers*, in which alone there is englacial rock débris. Wherever, therefore, glacier wastage goes on in the bottom layers, outwash deposition is to be looked for and, if found, deposits of loess are inevitable within the extramarginal zone to the outwash. Their age is that of the glacier itself, not that of an interglacial or post-glacial period, as has heretofore quite generally been assumed for Pleistocene glaciations.

In a paper published by the American Philosophical Society<sup>2</sup> it has been shown that the surface loess of the upper Mississippi Valley, hitherto described as "Peorian" and "Iowan," is in reality the loess of the Wisconsin glaciation, to which it occupies an extra-marginal zone, resting for the most part on the pre-Wisconsin glacial formations. This aspect of the behavior of continental glaciers requires that similar but more weathered loess deposits should be

<sup>2</sup> Hobbs, Wm. H., "The Glacial Anticyclone and the Continental Glaciers of North America," *Proc. Am. Philosoph. Soc.*, 86 (3): 388-402. 1943. *Idem*, "Wind and Soil," *Scientific Monthly*, 57: 289-300. 1943.

looked for in each of the older glaciations — the Illinoian, Kansan, and Nebraskan.

The deposits, described as "gumbotils" by their distribution, by their composition, both mechanical and chemical, and by their contacts, correspond well with such weathered loess deposits. These are the so-called "Kansan Gumbotil" with the "Illinoian Gumbotil," and the so-called "Nebraskan Gumbotil" when overlain by the Kansan drift. On the assumption that the gumbotils are weathered loess, that which overlies Nebraskan drift may otherwise be correlated with the "Kansan Gumbotil," which would be of Illinoian age.

Let us first consider the gumbotil of Iowa, which Kay and others have regarded as a weathered surface zone of the Kansan drift.<sup>3</sup> This gumbotil rests upon the pre-Illinoian (mainly Kansan) drift, and

is within the periglacial zone of the Illinoian glacier but outside its narrow zone of outwash. The Illinoian Mississippi flood plain was at the time the zone of marginal drainage (Figs. 2-3).

In its physical composition the gumbotil in Iowa is a loess with small included pebbles, also containing concretions and characterized by parting. This gumbotil was regarded as loess by Bain,<sup>4</sup> who said:

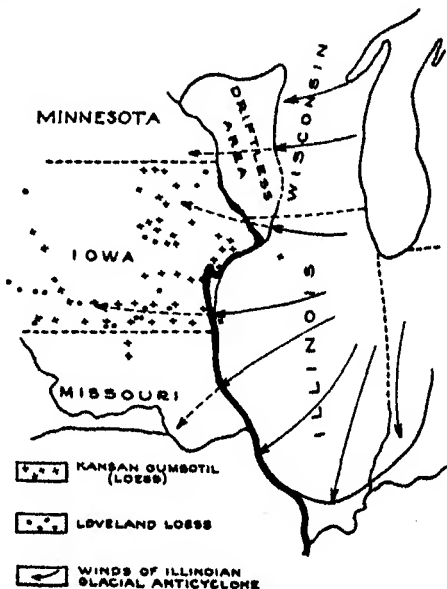


FIG. 2. Map showing the wind directions of the Illinoian glacier and over the post-Kansan gumbotil

<sup>3</sup> Kay, George F., and Pearce, J. Newton, "The Origin of Gumbotil," *Journ. Geol.*, 28: 89-125. 1920. Kay, George F., and Apfel, Earl T., "The Pre-Illinoian Pleistocene Geology of Iowa," *Iowa Geol. Surv.*, 34: 1-304. 1928. Kay, George F., and Pearce, J. Newton, "The Pre-Illinoian Pleistocene Geology of Iowa," *Iowa Geol. Surv.*, Spec. Rep., 282 pp. 1944.

<sup>4</sup> Bain, H. F., "Geology of Decatur County," *Iowa Geol. Surv.*, 8: 292. 1897. *Idem*, "Geology of Keokuk County," *ibid.*, 4: 302. 1894.

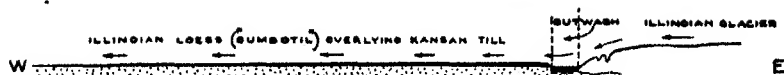


FIG. 3. Profile showing position of Illinoian loess

"It seems to be a deposit closely akin to the loess and is probably genetically related to it. Very likely it is but a phase of that deposit, though differing from it in its plasticity, color and density." Udden also held this view and wrote: "Probably it is mostly an old loess, which has been clogged up by interstitial deposition of fine ferruginous material through the agency of the ground water."<sup>1</sup> Except by Kay and his collaborators the gumbotils have generally been so regarded.

The following partial analyses show the close chemical relation of gumbotil to loess:

ANALYSES OF GUMBOTIL OF IOWA<sup>2</sup>

|                            | $\text{SiO}_2$ | $\text{Fe}_2\text{O}_3$ | $\text{Al}_2\text{O}_3$ | $\text{CaO}$ | $\text{MgO}$ |
|----------------------------|----------------|-------------------------|-------------------------|--------------|--------------|
| Foster, Monroe Co. ....    | 72.03          | 4.18                    | 12.27                   | 1.33         | 2.29         |
| Murray, Clarke Co. ....    | 70.46          | 4.17                    | 12.04                   | 1.21         | 0.55         |
| Warren, Carroll Co. ....   | 71.59          | 4.35                    | 12.79                   | 1.26         | 0.93         |
| Fort Madison, Lee Co. .... | 71.07          | 4.24                    | 14.91                   | 0.79         | 0.85         |

ANALYSES OF LOESS<sup>3</sup>

|                        | $\text{SiO}_2$ | $\text{Fe}_2\text{O}_3$ | $\text{Al}_2\text{O}_3$ | $\text{CaO}$ | $\text{MgO}$ |
|------------------------|----------------|-------------------------|-------------------------|--------------|--------------|
| Cherokee, Kan. ....    | 69.66          | 4.89                    | 12.71                   | 1.09         | 1.28         |
| Dubuque, Iowa ....     | 72.68          | 3.53                    | 12.03                   | 1.59         | 1.11         |
| Kansas City, Mo. ....  | 74.46          | 3.25                    | 12.26                   | 1.69         | 1.12         |
| Terre Haute, Ind. .... | 72.87          | 6.75                    | 11.25                   | 0.69         | 1.06         |

The profiles of gumbotil which have been published nearly always display a sharp contact with the underlying Kansan or Nebraskan, not a gradation into it; and generally the Kansan beneath shows a surface-weathered zone that is quite distinct from the overlying gumbotil, which is remarkably uniform throughout (Fig. 4). In one or two places where a gradational lower contact to the gumbotil

<sup>2</sup> Udden, J. A., "Geology of Pottawattamie County," *Iowa Geol. Surv.*, 11: 258. 1900.

<sup>3</sup> Kay, George F., and Pearce, J. Newton, "The Origin of Gumbotil," *Journ. Geol.*, 28: 116-118. 1920.

<sup>4</sup> Leverett, Frank, "The Illinois Glacial Lobe," *U. S. Geol. Surv.*, Mon. 38: 164. 1899.

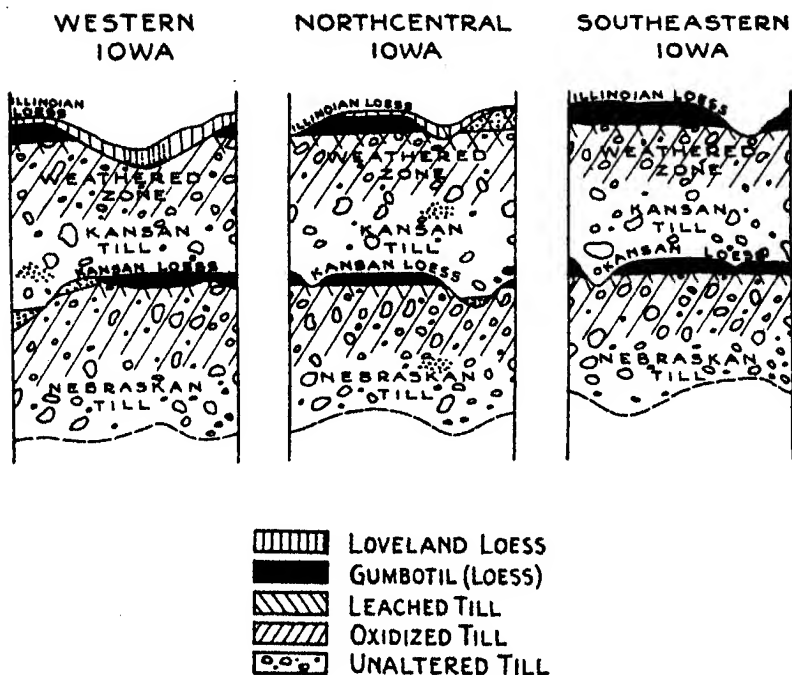


FIG. 4. Sections after Kay and Apfel, but with some names altered and upper portions omitted

has been described, the published photograph reveals a sloping surface with many small gullies suggesting a slumping of the material. Moreover, in the interpretations made the winds of the glacial anticyclone have not been taken into consideration as supplying a possible cause of the deposit.

An older gumbotil which rests on Nebraskan till and definitely underlies the Kansan till has been found by Kay and Pearce<sup>8</sup> in southern Iowa, by Shipton<sup>9</sup> in northern Missouri, and by Lugn<sup>10</sup> in Nebraska.

The Loveland loess found farther to the west in Nebraska has

<sup>8</sup> Kay and Pearce, *op. cit.*, pp. 98-99.

<sup>9</sup> Shipton, Washburne D., "The Occurrence of Nebraskan Drift in Northern Missouri," *Wash. Univ. Stud.*, 12 (Science Series 1): 53-71. 1924.

<sup>10</sup> Lugn, A. L., "Nebraska in Relation to the Problems of Pleistocene Stratigraphy," *Am. Journ. Sci.*, 237: 855.



been placed below with the "Kansan Gumbotil" by Lugn.<sup>11</sup> In their generalized section in Figure 4 Kay and Apfel have placed the Loveland *above* the gumbotil, but it occurs in the same horizon in separated localities.

A very thin layer of gumbotil has been found above the Illinoian loess in Lee County close to its border in southeastern Iowa, and also at other localities in Illinois, for example, at Galva in Henry County, some twenty-five miles inside the margin. These gumbotil deposits on the Illinoian have a thickness of a few feet only, whereas those near by on the Kansan are two to three or more times that thickness. It seems quite possible to explain these thin super-Illinoian deposits as having been formed when the glacier front was retreating, or, in part, after the planetary winds had invaded the waning anticyclone of the Illinoian from the west, and brought the dust which was raised by herds of bison, elephants, deer, and antelope that roamed the prairies of the Kansan. Such dust is elevated some tens of feet into the air and settles ever farther to the east. During the millenniums of the Illinoian-Wisconsin interglacial period such a thickness could be accounted for, and migration of loess in China along traffic lanes seems to warrant such an assumption.

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(March, 1944)

<sup>11</sup> Lugn, *op. cit.*, p. 84, fig. 3. *Idem*, "The Pleistocene History of Nebraska," *The Compass of Sigma Gamma Epsilon*, November, 1941, p. 22, fig. 2.

# **ANTHROPOLOGY**



## THE HOPEWELLIAN IN THE DETROIT-WINDSOR AREA

EMERSON F. GREENMAN

**I**N A former publication (3, 1939) I listed the sites of the Owasco aspect which were known for Michigan and Ontario at that time. Two more may be added, one at Clearville in Kent County, Ontario, where one of three components representing the second or intermediate occupation of the site allies it with the others in this list (7, p. 3, and pls. IV-XII), and another in Ash Township, Monroe County, Michigan. In 1940 the latter site was the scene of test excavations by Mr. Ralph Patton for the Museum of Anthropology of the University of Michigan, and the specimens brought forth, including crania with post-mortem perforations and disks cut from the occipital region (6), place the site in the Owasco aspect. This paper concerns only two of these eight sites, Rivière au Vase, near Mount Clemens, and Gibraltar, near the village of that name about fifty miles to the south at the mouth of the Detroit River. The pottery of both components of the Rivière au Vase site is described in another paper in the present volume (5).

At Rivière au Vase some three hundred burials in various degrees of fragmentation were excavated during the seasons of 1936 and 1937. Most of them were in a low elongated rise of ground at about the center of the site, an area which also contained a large number of refuse pits that had disturbed many of the burials. Toward the other end of the site at a distance of about a hundred feet, where the surface was level, there were five burials which appeared to represent a different occupation because of (1) their isolated position, (2) the fact that the skeletal material was in an advanced state of disintegration as compared with that of the other burials, and (3) the different character of the artifacts found with three of them. Two of the three, Numbers 2 and 5, consisted of adult skulls at depths of sixteen and nineteen inches in the light-gray sand of the site. Both skulls were brittle, white, and badly pitted and flaked, and large portions were missing as a result of disintegration. The other, Number 1, a torso of a young child, accompanied by the mandible

and a humerus, lay at a depth of thirty inches. There was little left of the vertebrae besides cancellous tissue, but the surfaces, if present, were white and brittle, which was true of the humerus also. The two remaining burials, Numbers 3 and 4, were in refuse pits which apparently belonged to the Owasco component. Number 4, an adult skull at a depth of only six inches, was in the same condition of decay as Numbers 1, 2, and 5. The only artifacts were a pot and eight chips of gray flint. Number 3 consisted of the pelvis and articulated leg bones of an adult, flexed, with a few ribs, hand bones, a radius, and two lumbar vertebrae, at a depth of twenty inches. With this deposit of bones were a pot (Pl. I, Fig. 5) and six pieces of split bird-leg bones. There is some doubt whether these two burials belong to this group. They are included because of their proximity to the others and because of the Woodland type of vessel found with each one, though since they were in refuse pits the association is questionable in both cases.

The only diagnostic Hopewellian trait exhibited by this group of burials was a copper rod with bone handle, found with Number 1, but many of the other objects with this burial and with Numbers 2 and 5 are of types that occur also at Gibraltar, where the Hopewellian designation rests on better evidence. The other artifacts with Number 1 are as follows: one quartz crystal, abraded at one end, one quartz flake, one projectile point of gray flint, triangular-unnotched, one truncated blade of black flint (Pl. II, Fig. 17), one T-shaped flint drill, one rectangular slate knife (Pl. II, Fig. 16), one small spatulate point of slate, and thirty-four cylindrical copper beads 4 mm. to 12 mm. long. The copper rod (Pl. II, Fig. 8) is 9.4 cm. long and 2.5 mm. square in cross section. One end is blunt, the other pointed, and the bone piece into which the point was inserted when found is 9 mm. long. This is without doubt all that remains of a handle which was originally a centimeter or two longer. It is the same type of implement as two others from the Seip mound (11, pp. 393, 410, fig. 34), one of which is much larger. Another (Pl. II, Fig. 9) was found in a circular depression about twenty feet in diameter in Waterloo Township, Jackson County, Michigan, by Mr. William H. Buettner, of the Museum of Paleontology of the University of Michigan, in 1923. It was at a depth of four feet. The cross section is square, and the remains of the bone handle still adhere firmly to the base of the rod. This depression, which

was about eighteen inches deep at the center and surrounded by a rim of earth not more than six inches high, is described by Mr. Buettner as being too symmetrical to have been the result of the excavation of a small mound at the center. Mr. Buettner also recovered a slate pendant (Pl. II, Fig. 14), a flint flake, and the vessel shown in Plate I, Figure 6, which has a notched lip and a design of diagonal incised lines in the neck area.

With Number 2 there were one pot, two pieces of two pendants of slate, each perforated, four projectile points of gray flint, six roughly oval to triangular blades of dark bluish-gray flint up to 4.5 cm. long (one is shown in Pl. II, Fig. 10), twelve flakes and blocks of the same type of flint, one half of a small disk of brown stone about 3 cm. in diameter, a piece of deer-leg bone, and a piece of antler, both unworked. Number 5 was accompanied by one pot, one granite celt (Pl. I, Fig. 1), one T-shaped drill of gray flint, fourteen flakes and blocks of bluish-gray flint, one ovate reject of the same material, one flake of black flint, and the base of an unnotched blade of brown flint, thin and well made.

In 1937 the Gibraltar site was discovered by unknown individuals and excavated in an unsystematic manner. This work attracted the attention of members of the Detroit Aboriginal Research Club, which, during independent excavations, found the Hopewellian material. Later on week-end excavations were carried out by them under my direction. Though several burials were uncovered during this period there was nothing to indicate Hopewellian affiliations. Most of that material was associated with burials evidently at greater depths than those ascribed to the Owasco aspect, and there is no information to the effect that any of it came from the surface or was between the original placements and the surface. There are likewise no data indicating whether the graves containing this material were dug down from the present surface or whether their tops were covered by subsequent accumulations during the occupation which deposited the Owasco materials. As at Rivière au Vase, the great majority of burials were in a low rise of ground not more than six feet above the general level, but those of the Hopewellian component were also in this knoll.

In Plate II, Figures 3-4, is a platform pipe which was excavated from the lower level of the site by Mr. Jerry McKenzie, of Detroit. It is about 13 cm. long, and the material is probably steatite. The

bowl is so thin as to be slightly translucent. In Plate II, Figures 1-2, is a much larger pipe of another type. It is an effigy of a flying bird, and the material is greenish-gray steatite. The length is about 20 cm. This pipe, found by Mr. Harry Hosack, of Detroit, was associated with a burial and the following objects: one end scraper of dark-blue flint, one roughly ground stone celt, one projectile point with oblique corner notches, one oval gorget-like piece of sheet copper nearly 10 cm. long with a small hole at the middle of one side, and three disks of bluish-black flint (Pl. II, Figs. 5-7).

In addition to these objects there are about one hundred and fifty in private hands or in the Museum collections as loans. Many are of types common to Hopewellian sites but are not diagnostic. Especially numerous are unnotched blades of dark-blue flint, ranging in length from 4 to 22.5 cm. and with bases straight or rounded. The bases of most of them are slightly constricted with reference to the widest portion. The largest of these (Pl. II, Fig. 18) is 22.5 cm. long and is one of five found with a burial by Mr. Norman Grogitsky, of Dearborn. The others are smaller, but all are thin and skillfully made. One blade of this same material is stemmed on one side only (Pl. II, Fig. 15). There were three unusually well made celts, two of black slate and a third of a closely textured dark-green material (Pl. I, Figs. 2-3; Pl. II, Fig. 12). One of the three (Pl. II, Fig. 12), which is about 20 cm. long, is flat on the side opposite that shown. The cross section of the shorter one is rectanguloid, and the two faces are slightly convex. Another specimen (Pl. I, Fig. 3) is oval in cross section, and the upper half is abraded and recessed on the sides as a hafting expedient.

A great many of the flint projectile points from the site are of the oblique corner-notched type (Pl. II, Fig. 11) common on Hopewellian sites in Ohio (11, fig. 48, lower row, the three at left). There are also several triangular-unnotched blades, most of them over 5 cm. long. One fragment of a stemmed blade of argillite, of a type found on the surface in Michigan and regarded as representing a very early occupation, is among the materials from Gibraltar, but its association is unknown. There are three T-shaped flint drills, one of them with side notches, several end scrapers of blue flint, and one "bunt." Objects of copper are represented by beads, the oval gorget already described, and a copper rod with a bone handle. There are thirty-three copper beads, which are cylindrical and of the same size as those from the Rivière au Vase. The one copper

rod with a bone handle, found by Robert Schneider, of Detroit, is 11.5 cm. long and 3 cm. square in cross section. The end set into the handle is pointed and penetrates it to a depth of 1 cm. The bone part is 1.5 cm. long and resembles that part of the similar specimen from Rivière au Vase (Pl. II, Fig. 8). Another copper rod, 3 cm. long and also square in cross section, is in the collection of Mr. Schneider. The copper gorget is 10 cm. long and has a small hole near the edge of one side. Several slate pendants came from the site, all with outlines similar to that of one from the Schneider collection (Pl. II, Fig. 13).

The pottery associated with the Hopewellian materials from the Gibraltar site is of the Woodland type like that from the corresponding component at Rivière au Vase. A typical one is shown in Plate I, Figure 4. Complete vessels range from 17 to 25 cm. in height and are so proportioned as to give a globular rather than an elongated appearance. This ware has moderately conical bases and wide mouths, and curved flaring rims predominate, though the straight rim, vertical or slanting outward, is present. On one vessel the rim is elevated to make four opposed points (Pl. I, Fig. 7), and on another, one of the few with a rounded base, the rim has one low scallop about 3 cm. long. The vessel is restored, and may originally have had more than one scallop. Surfaces are roughened by impression with cords or other implements, chiefly in blocks at various angles to one another. Decoration is incised or punctate, with the latter type dominant as linear patterns formed by impression at the end of a stick, with a cord-wrapped stick, or with the side of a stick in the lip. On two vessels there are cross-hatched bands of incised lines in the neck area, and on one of them the band is delimited by incised lines about 3 mm. wide. Another vessel has a crescent-shaped punctate pattern repeated on four sides of the body. On the vessel in Plate I, Figure 6, which has a more elongated appearance than any from the two sites under discussion, an incised zigzag pattern is crossed by horizontal lines. The whole design is carelessly executed over the cord-roughened surface.

This type of pot is one of the most important links between the Hopewellian and other phases of the Woodland pattern. It is found in the larger Hopewell mound groups in Ohio (12, pp. 90-93) and was formerly described as of Algonkian utilitarian type to distinguish it from the more ornate Hopewell type of pot, which was regarded as an expression of ceremonial attitudes toward the remains of the



dead (11, p. 436). This ware occurs at the Esch group (1; 4), and it is the same as that found in Hopewellian burial mounds in southwestern Michigan and northern Indiana (8, Pl. XVI, Figs. 7-8).

From this brief account of the finds at Rivière au Vase and Gibraltar it should be clear that the two sites have a Hopewellian component. At Rivière au Vase it was separated from the Owasco horizontally, whereas at Gibraltar the available evidence indicates that the separation was vertical. The only diagnostic Hopewellian trait in the Rivière au Vase component is the copper rod with bone handle, but objects of pure quartz and cylindrical copper beads are characteristic of that phase. The Hopewellian components at these two sites have the following traits in common: slate pendant, highly finished celt with rectangular cross section, flint projectile points with oblique corner notches, unnotched flint blade with flat restricted base, unnotched leaf-shaped flint blade, and the triangular-unnotched flint blade of the Woodland type; the T-shaped drill of gray flint, notched and unnotched, copper rod with bone handle, the cylindrical copper bead, and pottery of the same Woodland type, similar in size, shape, decorative techniques, and position of decoration. Three of these traits are represented in the material secured by Mr. Buettner from the site in Jackson County — the copper rod with bone handle, the slate pendant, and the Woodland type of pot.

The platform pipe from the Gibraltar site, which is of the plain type, is usually made of steatite and is found on Hopewellian sites marginal to the centers of more complex development such as that in southern Ohio. A pipe like this came from the smaller of the two Esch mounds near Huron, Ohio (1), where it was with a burial accompanied by other objects of types occurring at Gibraltar, namely, leaf-shaped blades of dark-blue flint, blades with straight bases (though not constricted), the Woodland type of triangular-unnotched flint blade with broad base, a slate pendant, and a small copper rod with bone handle and circular cross section.

A historical connection between the Gibraltar site and the Genesee mound in Livingston County, New York (9, p. 32, fig. 2), is indicated by the finding in that mound of two pipes, one of the simple platform type like that from Gibraltar and the other of the zoomorphic effigy type, of green sandstone. These two pipes are miniatures. The platform pipe is only  $1\frac{7}{8}$  inches in length and the other is  $2\frac{1}{8}$  inches in length. The latter is described as a platform pipe,

but I believe it to be a miniature of the large zoomorphic effigy type of pipe like that found at Gibraltar and at the Seip mound (11, p. 422, fig. 43). In this connection it is of interest that one of the two mounds of the Esch group contained also a zoomorphic effigy pipe, the subject of which is an alligator, but the shape is not like that of the pipes from Gibraltar and the Seip mound, and the material is Ohio pipestone (Sciotoville flint clay). The pottery of the Geneseo mound (9, p. 34, fig. 3) is similar to that of the Hopewellian components at Gibraltar and Rivière au Vase.

It cannot be shown either at Gibraltar or at Rivière au Vase that there was a developmental connection between the Hopewellian component and that component which predominated on both sites, which, whether it is finally termed Owasco aspect or not, in any event has in it elements of both the Woodland pattern and the Iroquois aspect. Nevertheless, more than a mere areal association is suggested by the presence of the Hopewellian on two different sites of the same character. The Hopewellian, even though its relationship to other phases of the Woodland is little understood, contains elements which could have initiated and maintained a development in the direction of the Owasco as that is represented in Michigan and Ontario, and the occurrence of Hopewellian on a sufficiently ample scale at two Owasco sites is consistent with such an interpretation. It is important to recall in this connection that the post-mortem perforation of crania and the removal of a circular disk from the occipital region (6; 2, pp. 35-42, 50, 54-55), two traits which are highly specific for the Owasco of the Detroit-Windsor area, are recorded for Mound 3, and Marriott Mound 1, of the Turner group (12, pp. 60-61, 124, pl. 27), and Mounds 7 and 25 of the Hopewell group (10, pp. 38, 93). Both traits occur also on at least two sites attributed to the Iroquois: the Lawson site in Middlesex County, Ontario (14, p. 36, pl. 13), and the Uren site in Norfolk County, Ontario (6, p. 9; 13).

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## EXPLANATION OF PLATE I

(Scale not uniform)

- FIG. 1. Granite celt, Rivière au Vase
- FIG. 2. Slate celt, Gibraltar
- FIG. 3. Celt of green stone, Gibraltar
- FIG. 4. Vessel, Gibraltar
- FIG. 5. Vessel from Burial 3, Rivière au Vase
- FIG. 6. Vessel from mound in Jackson County, Michigan
- FIG. 7. Vessel, Gibraltar



1



2



3



4



5



6



7

Celts and vessels from various sites

## EXPLANATION OF PLATE II

(Scale not uniform)

- FIG. 1. Side view of effigy pipe, Gibraltar
- FIG. 2. Top view of effigy pipe, Gibraltar
- FIG. 3. Top view of platform pipe, Gibraltar
- FIG. 4. Side view of platform pipe, Gibraltar
- FIGS. 5-7. Flint disks, Gibraltar
- FIG. 8. Copper rod, with fragment of bone handle at left, Burial 1, Rivière au Vase
- FIG. 9. Copper rod with bone handle, mound in Jackson County, Michigan
- FIG. 10. Leaf-shaped flint point, Burial 2, Rivière au Vase
- FIG. 11. Flint projectile point, Burial 2, Rivière au Vase
- FIG. 12. Slate celt or chisel, Gibraltar
- FIG. 13. Slate pendant, Gibraltar
- FIG. 14. Slate pendant, mound in Jackson County, Michigan
- FIG. 15. Flint blade with one shoulder, Gibraltar.
- FIG. 16. Slate knife, Burial 1, Rivière au Vase
- FIG. 17. Truncated flint point, Burial 1, Rivière au Vase
- FIG. 18. Large flint blade, Gibraltar



1



3



5



2



4



6



11



10



9



8



7



12



13



15



17



14



16



18

Pipes and implements from various sites



## CERAMIC COLLECTIONS FROM TWO SOUTH CAROLINA SITES

JAMES B. GRIFFIN

FOR various reasons South Carolina archaeology has not been developed so fully or so systematically as that of her neighboring southern states. The large and impressive mounds and village sites of the later aboriginal periods which enticed field archaeologists into Georgia, Tennessee, and North Carolina do not appear to be common in South Carolina. Thomas described but one site, the McDowell mounds, in his discussion of the mounds of the eastern United States,<sup>1</sup> and mentioned only a few sites for South Carolina in his catalog of sites known to the Smithsonian Institution in the latter part of the nineteenth century.<sup>2</sup> Holmes' study of the pottery of the eastern United States called attention to the prevalence of stamped ware in South Carolina with some traces of cord-marked and fabric-impressed pottery from along the Atlantic Coast.<sup>3</sup> The most recent publications on South Carolina are about the Beaufort area and are the result of survey work carried on by W. K. Moorehead.<sup>4</sup>

The two sites to be discussed in this paper are located near the Piedmont border of the Coastal Plain in the valleys of the Congaree and Wateree rivers. They are the first sites from this area to have their pottery described in present-day terminology.

### THOM'S CREEK SITE

In November, 1942, the Ceramic Repository for the Eastern United States received a shipment of pottery from Colonel Dache M. Reeves, of the Army Air Forces, from a site six miles south of Columbia, South Carolina. Colonel Reeves had been taken to the site by Dr. Chapman J. Milling, of Columbia, whose recent book on

<sup>1</sup> Thomas, 1894, pp. 326-327. The mounds are evidently across the river from the Cut-Off Island site described in this paper.

<sup>2</sup> Thomas, 1891, pp. 194-196.

<sup>3</sup> Holmes, 1903, pp. 139, 147-148.

<sup>4</sup> Flannery, 1943; Griffin, 1943.



the history of the Indian groups of the Carolina area has been an outstanding contribution.<sup>5</sup> The site is on the south side of the Congaree between the river and the old state road running from Columbia to Charleston. It is about six miles south of Columbia and is on both sides of Thom's Creek, although the major occupation was apparently on the south bank of the creek on land held by Ernest Hall.

In his book Milling suggests that the site of the Congaree village in 1715, located 120 miles from Charleston, was at a place three miles below Columbia, near Granby, which is locally known as "The Congarees."<sup>6</sup> He now believes their location to have been on Thom's Creek, his revised opinion being based on the large number of trade-pipe fragments found on it. The Congaree tribal group was a small one and even in 1701, according to Lawson, was comprised of fewer than a dozen houses. In the Indian Census of 1715 the Congaree are credited with one village, and their total number, including the related Santee, is given as 125. Thus the small size of the group and their evident frequent movements would not suggest any great depth of deposit from their occupation of a site.

TABLE I  
POTTERY FROM THOM'S CREEK SITE

| Type or dominant surface finish      | Rim | Body | Total |
|--------------------------------------|-----|------|-------|
| Stallings Plain .....                | 1   | ..   | 1     |
| Thom's Creek Punctate .....          | 7   | 12   | 19    |
| Fabric-impressed .....               | 1   | ..   | 1     |
| Cord-marked .....                    | ..  | 2    | 2     |
| Simple-stamped .....                 | ..  | 2    | 2     |
| Deptford Check Stamp .....           | 8   | 58   | 66    |
| Plain-surfaced .....                 | 2   | 17   | 19    |
| Complicated-stamped (late period) .. | 1   | 10   | 11    |
| Total .....                          | 20  | 101  | 121   |

All the pottery from the site can be said to belong to the early Woodland pottery tradition in the southeast, except for the complicated-stamped and some of the plain-surfaced specimens, which form a minority of the total recovered. The latter belong to the

<sup>5</sup> Milling, 1940.

<sup>6</sup> *Ibid.*, p. 213.

protohistoric and early historic period in the Georgia-Carolina area and were perhaps deposited at the same time as the large number of European white-clay pipe fragments and glass-bottle fragments found on the site.<sup>7</sup>

*Stallings Plain.* — One sherd, the only representative of its type, but in all probability further search and excavation will bring more specimens to light. It corresponds closely to the published description of this type,<sup>8</sup> but has a larger proportion of granular rock fragments in the paste than do the sherds from the Chester Field site. There is a biconical hole 1.5 cm. below the lip (Pl. I, Fig. 1E).

*Thom's Creek Punctate.* — A group of pottery fragments, probably the most interesting from the site. Their decoration is very close to that of Stallings Punctate and is probably derived from that type (Pl. I, Fig. 1A-D, F-L). Whereas Stallings Punctate sherds are fiber-tempered, these specimens either have very little tempering or are grit-tempered with a relatively small amount of crushed-rock particles resembling the material used in the Deptford Check Stamp type at this site. Another noticeable difference is that they average 5 to 7 mm. wide and are thus noticeably thinner than the usual fiber-tempered ware of the coastal area. Almost all the punctations are placed in horizontal rows paralleling the lip. Three out of the nineteen sherds have them in an arrangement which has been called "linear-punctate" (Pl. I, Fig. 1A). These, as well as the majority of the punctations, could best have been placed on the vessel when it was held by the left hand with the orifice to the right. Some of the rim sherds indicate a wide-mouthed bowl with almost vertical walls and flattened lips, whereas others indicate an incurving rim markedly restricting the orifice, and on these the lip is rounded, or narrowed and rounded. The color is usually light buff to light brown on both surfaces and in the cross sections. The hardness is 2-2.5. The pottery was coiled or built by annular rings, and both surfaces were smoothed before they were decorated.

*Fabric-impressed.* — A fragment belonging to the early fabric-impressed types of the southeast, already well described in the literature. This particular sherd apparently was locally made, as is indicated by the strong resemblance of its paste and tempering

<sup>7</sup> Dr. Milling has kindly furnished considerable additional information and specimens.

<sup>8</sup> Griffin, 1943, pp. 159-160.

material to the dominant Deptford Check Stamp type. The warp impressions are horizontal to the lip on the outer rim; on the inner rim similar impressions are placed vertically (Pl. I, Fig. 1 M). The lip is narrowed and rounded.

*Cord-marked.* — Body sherds also to be associated with the Deptford period at this site (Pl. I, Fig. 1 O).

*Simple-stamped.* — Two body sherds. One of them with this type of surfacing is connected with the Thom's Creek Punctate type on the basis of the width of the body wall and the relatively sparse tempering, whereas the other is thicker, has a considerable amount of crushed-rock temper, and in those respects resembles the Deptford pottery (Pl. I, Fig. 1 P).

*Deptford Check Stamp.* — Specimens having, almost without exception, coiled-fracture surfaces on either their upper or lower margins. One fragment is a single coil width, 1.2 cm. in height (Pl. I, Fig. 2 G). The majority of the sherds are of this type, which has been competently described by Caldwell and Waring.<sup>9</sup> The full description has not yet appeared in print, so that it is necessary to discuss these sherds in some detail.

The tempering material is fine to medium-coarse sand particles, rounded to subangular, and varying considerably in color. There is a high proportion of sand to clay. Some of the interior surfaces have the appearance and feel of sandstone. The texture is medium-fine to medium-coarse, and the hardness is 2-2.5. The exterior surface is almost always a reddish to yellowish buff and, in an unusually high percentage of the pieces, this color penetrates through the core to the inner surface. This suggests firing in an oxidizing atmosphere, but some specimens, otherwise exactly the same, were fired in a reducing atmosphere, as is indicated by their dark-brown to black cores. These latter sherds have only a thin layer of light-colored clay on the surface, which is sometimes eroded away, revealing the unoxidized interior.

The inner surfaces were smoothed, but only rarely were they worked sufficiently to bring the finer clay particles to the surface to form an even uniform film over the tempering particles. Consequently the temper protrudes with a resultant sandstone-like appearance. The exterior surface was given some preliminary working

<sup>9</sup> Caldwell and Waring, 1939.

before the application of the check stamp, but it also was not carefully prepared for the stamping.

In the mimeographed description of the Deptford pottery types two divisions of Deptford Check Stamp are recognized. These are called "linear-check stamp" and "bold-check stamp." The original descriptions are adopted here with but little modification. The linear-stamped impressions could have been rouletted or rocked on the vessel wall with a carved wooden rocker or cylinder. This is indicated by the great length of the individual impressions, by the warping of the design (Pl. I, Fig. 2K), and by overstacking (Pl. I, Fig. 2J). The impressions could also have been made by a single notched, narrow wooden or bone stamp. The design consists of a repeated parallel arrangement of two longitudinal lands,<sup>10</sup> which contain a series of finer transverse lands. The application of the stamp was often so carefully made that the entire series of longitudinal lands has the superficial appearance of having been executed by a single stamp. The longitudinal lands are invariably heavier and usually higher than the transverse lands. There is considerable variation in the width of the longitudinal lands themselves, which range from 2 to 6 mm. They may be either rounded, sloped, or flat. The stamp impressions were applied either obliquely (Pl. I, Fig. 2A, D, F, I, N), slanting from the lip downward to the right or parallel to the lip (Pl. I, Fig. 2B, C, H). The impressions were applied over the entire exterior surface.

There are a few sherds from the Thom's Creek site which indicate that a stamp was used producing three longitudinal rows of square depressions (Pl. I, Fig. 2E). Another sherd has the exact appearance of the dentate stamping on the fiber-tempered ware from northern Alabama,<sup>11</sup> and of dentate-stamped early Woodland pottery from the northern sections of the country (Pl. I, Fig. 2M).<sup>12</sup> One or two examples may have been paddled with a larger implement, such as was used by Holmes.<sup>13</sup> One of these sherds shows very small depressions (Pl. I, Fig. 2L).

The rim shape is straight, vertical, or slightly flaring. The lip is rounded and may also bear stamped impressions. There are no

<sup>10</sup> "Land" is used here in sense 8 of *Webster's New International Dictionary*, Second Edition.

<sup>11</sup> Griffin, 1939, pp. 139-140, 158-160.

<sup>12</sup> Ritchie, 1940, Pl. XXX; Wilford, 1941, p. 241.

<sup>13</sup> Holmes, 1903, p. 78.

folded rims. The bases are rounded or conoidal on the majority of known specimens, but some basal fragments from this site suggest a conical tetrapodal support (Pl. I, Fig. 20). The thickness ranges from 5 mm. to 1.2 cm., with the majority of the sherds having a thickness of 7 to 9 mm.

*Plain-surfaced.* — One rim and two body sherds of a group, probably belonging to the type called "Thom's Creek Punctate" (Pl. I, Fig. 1Q). The others have a paste analogous to that of the complicated-stamped specimens to be described below.

*Complicated-stamped.* — Fragments belonging to the late ceramic period of the South Appalachian area, when there was a noticeable decline in the skill and effectiveness with which the vessel walls were stamped. The designs on the specimens are indistinct, but some are concentric diamonds and others are concentric circles (Pl. I, Fig. 1S-U). The single rim sherd has a horizontal row of incised squares 1 cm. below the lip (Pl. I, Fig. 1R). A single sherd is decorated with a curvilinear double row of small punctations bordered by a narrow shallow incised line (Pl. I, Fig. 1N). Its paste characters resemble Thom's Creek Punctate. The exact affiliations are unknown. A complicated-stamped sherd has paste characteristics like the Deptford Check Stamp and probably belongs to the early period at this site (Pl. I, Fig. 2P).

#### DISCUSSION

The majority of the pottery from the Thom's Creek site very clearly belongs to the Deptford complex, which can be considered an early Woodland manifestation in the southeast.<sup>14</sup> The closest related pottery is to the south and southeast of Columbia, in the Augusta and Savannah areas of Georgia. If any of the pottery from the site was made by the Congaree around 1715, it would be the complicated-stamped pottery. This site would evidently well repay excavation and should help to settle the question of the types of native pottery which were common at this late contact period. If the Congaree made predominantly complicated-stamped pottery during the early historic period, it would agree with the possible Sewee ceramic complex along the coast.<sup>15</sup> On the other hand, most of the complicated-stamped pottery of this period was apparently

<sup>14</sup> Caldwell and McCann, 1941, pp. 50-51.

<sup>15</sup> Gregorie, 1925, Pl. VIII.

made by the eastern Muskogean and Cherokee groups, with a less marked use among North Carolina Siouan tribes. Further field work in this area should supply a definite answer to the question of the type of pottery made by the South Carolina Siouan tribes.

## CUT-OFF ISLAND

The pottery in the Ceramic Repository from Cut-Off Island was presented by Mr. E. Y. Guernsey, who collected it during the last world-war period. The material was gathered from the surface of the site. Mr. Guernsey says: "I have never seen more pottery at any location, and I presume even a casual 'dig' would have been

TABLE II

## POTTERY FROM CUT-OFF ISLAND

| Surface finish or decoration     | Rim | Body | Total |
|----------------------------------|-----|------|-------|
| Check stamped.....               | 1   | 2    | 3     |
| Punctate .....                   | ..  | 1    | 1     |
| Fabric-impressed .....           | 1   | ..   | 1     |
| Straight-line stamped .....      | 4   | 21   | 25    |
| Cord-marked .....                | ..  | 3    | 3     |
| Complicated-stamped .....        | ..  | 1    | 1     |
| Incised .....                    | 2   | ..   | 2     |
| Plain-surfaced grit-tempered ... | 4   | 1    | 5     |
| Plain-surfaced shell-tempered .. | ..  | 1    | 1     |
| Total                            | 12  | 30   | 42    |

most productive."<sup>16</sup> The site is on a small island in the Wateree River almost due east of Lugoff, Kershaw County, South Carolina. It is probably the area called "Friend's Neck" on the Hagood Quadrangle sheet of the United States Geological Survey. There is also the possibility that it is the "cut-off area" identified by Squier and Davis,<sup>17</sup> which is across the river from a fairly large group of mounds. The Wateree were living in this area around 1700,<sup>18</sup> but there is no indication of trade connections with Europeans in the collection made by Mr. Guernsey, although the pottery does not suggest any great antiquity.

With the single exception of the plain-surfaced shell-tempered

<sup>16</sup> Personal communication from E. Y. Guernsey.

<sup>17</sup> Squier and Davis, 1848, Pl. XXXVII, No. 2.

<sup>18</sup> Mooney, 1894, p. 81.

sherd all the pottery from this site is grit-tempered. Since the pottery types for this area have not been defined and since this collection is too small, the pottery is described below in the discussion of the surface finish or decoration.

*Check stamped.* — Rectangular stamp impressions, applied by a true grid stamp of either clay or wood. The rim sherd is from a vertical-walled bowl (Pl. II, Fig. 1 F). The lip is crudely flattened and is of uneven height around its circumference. The interior is roughly smoothed and bears finger impressions where the inner wall was held during the application of the stamp. The tempering is crushed rock, and the texture is medium. The color is smoke-blackened gray. One of the body sherds is of the same tempering material, a light-gray exterior and a dark unoxidized core (Pl. II, Fig. 1 G). The second check-stamped body sherd has a sandy paste and a light-brown exterior (Pl. II, Fig. 1 H).

*Punctate.* — A medium-coarse grit-tempered buff-colored sherd from the lower-rim area. There are three horizontal rows of left oblique deep, narrow rectangular punctates (Pl. II, Fig. 2 H). I do not have any record of a similar type.

*Fabric-impressed.* — A sherd with medium-coarse abundant crushed-rock temper. It has a brown exterior and interior surface and a black core. It is related to the widespread fabric-impressed Woodland ware, which begins as one of the earliest types in the area but which also continues up to the historic period in the eastern Virginia-North Carolina area to the north. Unfortunately the impression of the positive is indistinct but indicates narrow-warp strands 3 mm. apart and irregularly spaced narrow-weft strands with an over-one-under-one plaited weave (Pl. II, Fig. 1 L). The appearance of the sherd and the fabric are not duplicated in the collections in the Ceramic Repository. The lip is flattened and fabric-impressed. The vessel was a shallow basin much like the Middle Mississippi salt pan in shape. The body thickness is 7 mm.

*Straight-line stamped.* — The predominant surface finish. Some of the sherds so classified may have been malleated with a cord-wrapped paddle, but in such a manner that the cord impressions are not distinct.<sup>19</sup> The impressions range from a close approach to a simple stamped or brushed appearance to one which is a "straight-line stamping" to simple cord-marked (Pl. II, Fig. 1 A-E).

<sup>19</sup> Griffin and Angell, 1935, Pl. II, Fig. 2.

All the sherds are grit-tempered, with some variation in the amount and type of tempering material. A few have a sandy appearance and feel. The majority contain granular particles which appear to be predominantly quartzite. The texture is medium-fine to medium-coarse. These sherds are gray to grayish buff. The core is almost entirely dark gray to black. Both surfaces are poorly smoothed, so that the tempering material is often quite distinct. The lip is rounded to slightly flattened. The rim shape indicates a vessel with a vertical rim and a rounded to slightly conoidal base. One sherd possesses a biconical hole 1.5 cm. below the lip such as was used in the crack-lacing method of preserving a cracked vessel (Pl. II, Fig. 1D). One rim has a short everted upper segment with a closely spaced row of punctations on the lip. This is the only example of rim embellishment such as becomes common on the rims of the Irene-Lamar period complicated-stamped jars (Pl. II, Fig. 2E).

*Cord-marked.* — Three body sherds that may actually belong in the same division as the straight-line stamped sherds, but the cord impressions are clearly seen on the surface. Two of the sherds have a very sandy feel and a light buff exterior, and are somewhat thicker than the sherds listed as straight-line stamped (Pl. II, Fig. 1J-K). The third body sherd had limestone temper, but the particles were leached (Pl. II, Fig. 1I).

*Complicated-stamped.* — A sandy-tempered sherd having a dark-reddish exterior with a curvilinear rather shallow stamp impression (Pl. II, Fig. 2G). The inner surface is well smoothed and smoke-blackened.

*Incised.* — Two very sparsely tempered thin (4-5 mm.) rim sherds with an incised design on the outer rim and with vertical lines intersected by horizontal lines (Pl. II, Fig. 2I-J). I do not know of any similar examples.

*Plain-surfaced grit-tempered.* — Specimens with crushed-rock temper of noticeably smaller size than the straight-line stamped sherds and a medium-fine texture. Three of these are bowl rims. The largest sherd has a small horizontal lug 2 cm. below the lip, with six small punctate impressions on its surface (Pl. II, Fig. 2A). A similar row of closely spaced punctates is placed on the lip surface, which is flattened and slopes inward. On the other two bowl rims there are punctate impressions on the surface at the lip level (Pl. II, Fig. 2B-C). These are larger and deeper and are spaced farther



apart than those on the largest rims. Both exterior and interior surfaces of all three bowl rims are well smoothed. The fourth plain rim is from a wide-mouthed jar with an everted rounded lip which has a closely spaced row of small punctate impressions on the lip surface (Pl. II, Fig. 2F). It is of the same type of tempering material, texture, and smooth blackened interior of the complicated-stamped sherd.

*Plain-surfaced shell-tempered.* -- A sherd having a small amount of shell temper, which was leached from both surfaces (Pl. II, Fig. 2D). The exterior and interior surface color is a reddish tan; the core is a light blue gray. This sherd has the appearance of the body sherds from the small log town-house sites in the Norris Basin.<sup>20</sup> It is an anomaly at the site.

#### DISCUSSION

It is difficult and perhaps even foolhardy to attempt an allocation of this ceramic complex to a chronological position, yet on the basis of the material at hand suggestions toward that end will be made. The absence of the pottery types of the early Woodland period of the southeast, such as those from a site in Barnwell County,<sup>21</sup> which are now in the Ceramic Repository, and the small number of sherds of the full-blown Irene-Lamar complexes suggest that this site was occupied just before the period when the complicated-stamped was the most prominent method of surfacing the jars and bowls.

That such a late occupation had residence in this area is indicated by the pottery, illustrated in Schoolcraft, which was obtained near Columbia after a flood in the Congaree in 1852.<sup>22</sup> This material includes wide-mouthed jars with curvilinear and rectilinear complicated-stamped patterns and the check stamp as well. A specimen of a jar of this shape was 19 inches high and had an oral diameter of 14 inches. Another vessel was about 14 inches high, with a lip diameter of 13 inches. The bowls have a plain surface and a flat circular base with outslanting sides and an incurving rim. The lip is turned toward the interior and is sometimes plain and sometimes crimped or serrated. The measurements of one such vessel give a diameter of 16 inches and a height of 5½ inches; the flat base has a

<sup>20</sup> Griffin, 1938, pp. 289-293.

<sup>21</sup> Early Woodland material has also been reported from the Piedmont area. Fewkes, 1928, Fig. 187 A.

<sup>22</sup> Schoolcraft, 1852, Vol. II, Pl. 16.

diameter of 4 inches. Such pottery was in style during a period which is now estimated to have been approximately from 1550 to 1700. The pyramidal mound across the river from Cut-Off Island should be culturally connected with pottery types similar to those just described and to the bowls and complicated-stamped sherd from the Cut-Off Island site.<sup>23</sup> The illustration in Schoolcraft of a ceremonial axe which was obtained from near Camden also belongs to this same general aboriginal period.<sup>24</sup> Part of the ceramic complex from Porcher's Bluff near Charleston, South Carolina, is also corroborative of the presence of established populations in southern South Carolina from the coast to the mountain area during the late Middle Mississippi period.<sup>25</sup>

#### SUMMARY

Though the additional evidence of the prehistoric occupation of South Carolina presented in this paper is admittedly not extensive or conclusive, certain valuable statements can be proposed. The area south and west of the Wateree-Santee drainage has had a lengthy occupation beginning at least as early as the introduction of fiber-tempered pottery into the southeast. Following this, the early check-stamped types, as exemplified by the Thom's Creek site, show the influence of ideas continuing from the preceding period and also of concepts which are associated with the Woodland cultures to the west and north.

If the Cut-Off Island pottery complex of straight-line stamping, cord-marked, and check-stamped is found at other sites in the area, considerable support will be given to the hypothesis that such an association of ceramic elements is subsequent to the early Woodland sites. In the late aboriginal sites, dating roughly from 1500 to 1650, the complicated-stamped pottery becomes dominant and in the major sites is associated with the pyramidal mounds. This should be true of the McDowell site across the river from Cut-Off Island. The possibility is presented that both the Congaree and the Wateree were making complicated-stamped pottery as late as 1700-15, but this association, suggested by the remains from the Thom's Creek site, could hardly be regarded as demonstrated.

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<sup>23</sup> Thomas, 1894, pp. 326-327.

<sup>24</sup> Schoolcraft, 1857, Vol. VI, Pl. 44.

<sup>25</sup> Gregorie, 1925, Pl. VIII.

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## PLATES I-II

## EXPLANATION OF PLATE I

### FIGURE 1

- A-D, F-L. Thom's Creek Punctate
- E. Stallings Plain
- M. Fabric-impressed
- N. Punctate
- O. Cord-marked
- P. Simple-stamped
- Q. Plain rim
- R. Beaded rim of late ceramic period
- S-U. Complicated-stamped sherds of late ceramic period

### FIGURE 2

- A-D. Deptford Check Stamp rim sherds
- E-K, N-O. Deptford Check Stamp body sherds
- L. Check-stamp sherds with unusual small pattern
- M. Deptford dentate-stamped sherd
- P. Complicated-stamped sherd of Deptford period

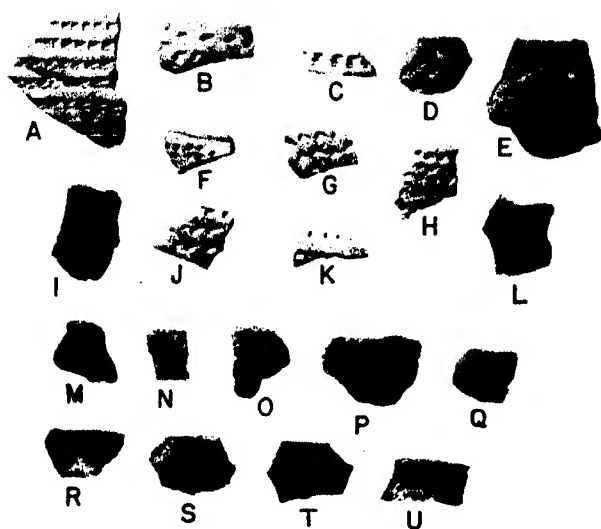


FIG. 1

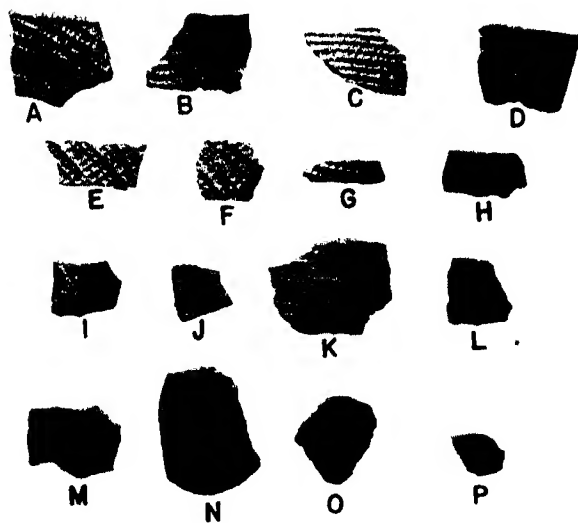


FIG. 2

Pottery fragments from the Thom's Creek site

## EXPLANATION OF PLATE II

### FIGURE 1

- A-E. Straight-line stamped
- F. Check-stamped rim sherd
- G-H. Check-stamped body sherds
- I-K. Cord-marked body sherds
- L. Fabric-impressed rim sherd

### FIGURE 2

- A-C. Plain bowl rims
- D. Plain shell-tempered body sherd
- E-F. Jar rims with punctations on the lip surface
- G. Complicated-stamped body sherd
- H. Horizontal rows of punctations
- I-J. Incised rim sherds

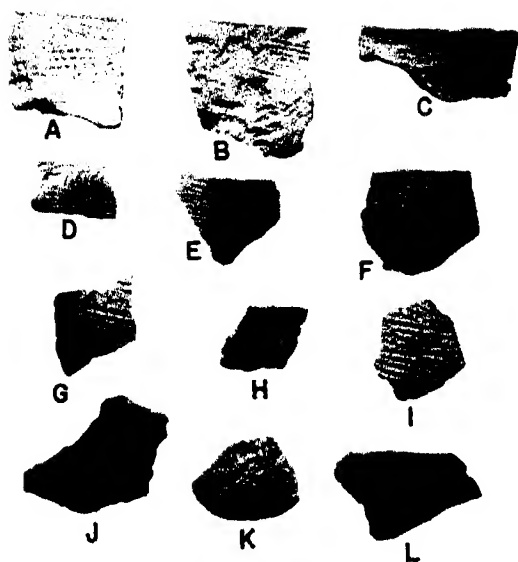


FIG. 1

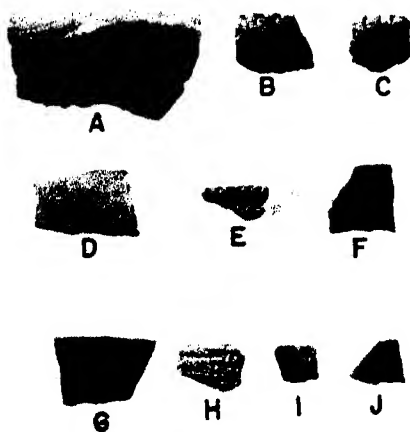


FIG. 2

Pottery fragments from the Cut-Off Island site





# A CERAMIC STUDY OF THE RIVIÈRE AU VASE SITE IN SOUTHEASTERN MICHIGAN

VICTORIA G. HARPER

## INTRODUCTION

**I**N THIS study I have done two things: first, I have made a ceramic analysis of materials from the Rivière au Vase site; and, secondly, I have compared this site with three near by on the basis of ceramic analysis. The others are the Wolf, Furton, and Younge sites. The problem of comparison is of considerable interest because of the diversity of classification of the four sites. Greenman (3, p. 35) places the Younge, Furton, and Rivière au Vase in one focus and assigns the Wolf site to an entirely different phase.

## LOCATION OF THE SITE

The Rivière au Vase site is located in southeastern Michigan about three miles northeast of Mount Clemens and one-half mile inland from the shores of Lake St. Clair. It is near a small creek on a low, sandy ridge which runs parallel to the shores of the lake. Geologically the area is within the Port Huron morainic system of the Huron-Erie ice lobe, which dates from the last stage of Pleistocene glaciation. The ridge upon which the site is situated is probably an old beach of Lake St. Clair.

There were, and still are, ample resources here for the development of the ceramic art by the Indian, and an abundant supply of clay is to be found on the banks of a neighboring stream also; the whole region is fairly rich in a good-quality clay which is used commercially today (1, p. 314). In addition to clay, many kinds of tempering materials occur, including a red-burning sand and many kinds of rock, mainly granites and syenites, with some sandstone, quartzite, and flint, all of glacial origin. There was also ample wood in the area at the time of Indian occupation.

## CERAMIC MATERIALS

The pottery obtained from the site, a crude, grit-tempered ware, is characteristic of the Woodland culture. Greenman (4, p. 461) has described one of the two components on the basis of style and decoration. The first component, the later one, belongs to the Owasco Aspect of the Northeastern Phase of Woodland culture. The range in style of shape and design is from pure Woodland to Iroquois with incised chevron designs and castellations along the vessel rims. The second, which is the earlier, is a Hopewell-like component, so classified on the basis of the stone and copper artifacts found at the site. The pottery is finer-textured, and the walls of the vessels are thinner, with characteristically Woodland shapes and decorative technique.

A total of 1,044 sherds from the collection of about 3,000 from the first component was examined under a binocular microscope in order to determine differences in tempering material. Fifteen sherds and seven pipestems representative of the ware from the first component were thin-sectioned for detailed petrographic study.

Materials from the site were tested so that comparisons could be made. The only clay near by was a dark, bluish-gray variety on the bank of the dredged Rivière au Vase. A sample of the ridge-forming sand, as well as numerous rock types, was obtained for experiment. I wished to see just how closely these materials would resemble the sherds already gathered. The following tests were made: materials (under the microscope), firing, water of plasticity, and linear-drying shrinkage.

## MICROSCOPIC EXAMINATION

The clay from the site was subjected to various tests to determine its mineral composition. It proved to be rather calcareous, reacting readily when tested with hydrochloric acid. A bromoform heavy mineral separation yielded only hornblende, magnetite, and a few fragments of zircon. Examination of thin sections of clay pellets fired to 800° C. revealed the following minerals: quartz, orthoclase, and an acid plagioclase, probably albite. None, however, occurred in abundance, and all were under 0.073 mm. in size. A microscopic study of sand from the ridge revealed, aside from the main quartz constituent, microcline, orthoclase, and albite. The size of these

minerals ranged from 0.073 to 0.292 mm. Hornblende and magnetite as large as 0.146 mm. were also found.

A study was made of a thin section of a clay pellet containing 25 per cent, by weight, of crushed rock temper, composed of rock obtained from the site. Many of the minerals already observed were present in large amounts as rock constituents. They included quartz, feldspar, mainly microcline, orthoclase, and an acid plagioclase; as well as biotite, hornblende, augite, and the alteration products sericite and kaolinite, which thickly covered the feldspars. A thin section of a pellet composed of clay and 20 per cent, by weight, of sand was also examined. The minerals already listed for the sand were noted, namely, quartz, microcline, orthoclase, and albite, together with hornblende and magnetite. The mineral particles were rounded for the most part and were within a maximum size of 0.292 mm.

My analysis of materials from the site gives a picture of the nature of the materials available for ceramic manufacture. The composition of clay and the variety of tempering material is known. With this information in mind we can now study the sherds and compare their composition with materials from the site. In this way it is possible to learn more exactly the provenience of the pottery — whether it was local or imported.

Of the 1,044 sherds of the first component examined for tempering material under a binocular microscope 998, or 95.6 per cent, showed a grit temper, rock particles made up of quartz, mica, and a feldspar; the remaining 46 sherds, or 4.4 per cent, revealed little or no temper. The tempering material consisted of sand and crushed rock, mainly sandstone and granite, with a little syenite. Quartz, orthoclase, acid plagioclase, sericite, kaolinite, biotite and muscovite, magnetite, and hornblende were found, quartz being the most abundant and hornblende very scarce. The range of size for the various minerals was from 0.073 to 2.2 mm. Quartz and the feldspars are the most important groups of minerals. Most of the feldspar occurs within the sherds as a rock constituent along with pieces of quartz and the micas, muscovite and biotite. Because of the occurrence of these types of feldspars we are able to identify the rock used as granites and syenites, for these members of the feldspar group occur only in these rocks. It will be remembered that granite was found in abundance at the site, and much of it was extremely weathered

and very friable. In addition to the minerals noted above, blackish and reddish lumps of iron were observed frequently in all sherd slides. These indicate a rather ferruginous clay, poorly fired, as is shown by the black iron lumps, and a clay also poorly pulverized, as one might infer from the size of the lumps, which range from 1 to 1.5 mm. The clay itself exhibits a varied appearance under the petrographic microscope; most of it seems to be low-fired, with much carbon in the interior, whereas the outer edges are reddish and rather bright in polarized light. At higher firing temperatures the organic matter which gives the black appearance to the core would be oxidized to carbon monoxide and carbon dioxide, and thus be burnt out of the clay.

Study of the thin sections of sherds from the first component has shown that all the pots were made from the same clay and much the same tempering material. In a few slides there are isolated rounded quartz particles, which suggest a stream clay, but in others the quartz is not so obvious. This might indicate a small local variation in the clay deposit, particularly if it was obtained from the banks of the Rivière au Vase.

The much more finely made pottery from the second component, though it appears quite different in gross aspect from the first component, looks quite similar under the microscope. Tempering material is finer and sparser, however, but again the most abundant mineral is quartz, and the size range is microscopic to 1.46 mm., about half as large as that in the first component. The feldspars, with the exception of microcline, the micas, biotite and muscovite, hornblende, magnetite, sericite, and kaolinite, are the other minerals noted in these sherds. Except for a very friable well-fired orange-colored sherd, which, however, had a similar mineral content, this group seems very homogeneous. It is probably safe to say that the pottery from this component was made of the same sort of materials as the ware of the later component. The rock temper, though a little different, is still granite, and the clay has the same appearance under the microscope. The difference seems to be not in materials used, but in the techniques of manufacture and firing.

The pipestem thin sections prove to be quite similar to those of the foregoing description. Though not very thoroughly fired, the pipes are rather well made, for the temper is fine, being almost a part of the paste. Quartz is again the most prominent mineral, and a

few particles as large as 1.46 mm. are found. Muscovite and biotite, an acid plagioclase, magnetite, flint, sericite, and rock fragments complete the list. The sizes range from microscopic to 0.87 mm. The outstanding mineral, aside from quartz, is biotite, which occurs frequently throughout the sampling.

We may now draw a few conclusions. Perhaps the first and most obvious thing is the fact that the tempering material is not only coarse, but, for the most part, unnecessary. The texture of the temper would make the clay much more difficult to work than it would be if it were not tempered, and the volume of temper is far too large to serve efficiently as an aplastic.

A comparison of the sample materials from the site with the sherds indicates that the pottery was probably made from local materials. The granite found at the site was extremely weathered and friable. This condition shows up in the thin sections of the sherds owing to the presence of a large amount of sericite and kaolinite. The granite, it might be noted, would have been very easy to handle since the potter would have had only to crumble it up to make it ready for use.

There is a slight possibility that much of the clay may have been sandy, which would account for the abundance of quartz, but not many of the sherds have a distinctly sandy feel. To judge from the size of most of the quartz particles, it would seem that the quartz had been added in the form of sand and as a rock constituent. The clay gathered from the site has very little sand in its composition, another reason for assuming the addition of sand.

The pipestems are fairly uniform in appearance, and some of the thin sections give the impression of being untempered, but others have a little coarser texture. The potter may not have bothered to levigate the clay, or it may be that fine sand was added.

#### PHYSICAL PROPERTIES

##### *Hardness*

The hardness of the Rivière au Vase pottery of both components is well within the range of the major portion of the eastern United States ceramic material. According to Moh's scale of hardness (see 5, pp. 17-22), it ranges from 2.5 to (or almost to) 3. Even the pipestems, which are more homogeneous than the sherds, showed the

same range. In terms of this scale this means a fairly soft ware. The pottery at the Younge,<sup>1</sup> Wolf, and Furton sites (3, p. 13) has much the same range, from 2 to 3.

### *Surface Finish*

There is little variation in surface finish, for smooth-surfaced pieces are very common. The coarse tempering material seldom mars the smooth finish of the sherds, although it does show through in many places. All sherds are perfectly smooth and plain on the interior. Those from the second component, with few exceptions, are cord-marked, with a smoothed interior.

### *Texture*

According to Miss Shepard's classification of texture (7, pp. 409-411), this pottery is very coarse because of the addition of large quantities of grit temper, which ranges from 0.5 to 2 mm. The sherds from the second component fall into the coarse to very coarse classification, and the temper averages about 0.5 to 1.3 mm.

### *Color*

The Rivière au Vase sherds have the characteristic Woodland pottery colors — smoky grays and browns, with occasional well-oxidized pieces in light buffs and cinnamons. Color in pottery is, of course, significant. Differences in color may be due to the variety of materials, to variations in technique of manufacture, or to circumstances such as handling with dirty or greasy hands. Variations due to firing will be discussed later.

In establishing color groupings Robert Ridgway's *Color Standards and Color Nomenclature* (6) was used. Four hundred and seventeen sherds from the first component were divided into three groups. Group I, 24.5 per cent of the total, represents the well-fired sherds in the buffs and cinnamons. Group II, the largest one, comprising 52.2 per cent, is within the brown and grayish-brown ranges and contains many of the sherds that are covered with secondary carbon. Group III, with 23.3 per cent, contains sherds of mouse grays and dark grays. Of 181 sherds of the second component the majority fell within the buffs and grayish buff. A small group of less than a dozen was in the orange-cinnamon range.

<sup>1</sup> Matson, Frederick R., in Greenman (2, p. 102).

The pipestems, also, were quite uniform in appearance, although two color groups could be distinguished: brownish gray and the lighter buff colors. The first group contains 29 of the 60 pipestems; the second group, 31.

### *Working Properties*

When clays are prepared for firing many properties can be determined which are very useful for descriptive and comparative purposes. Two of those most easily determined are the water of plasticity and the linear-drying shrinkage observed in working the clay preparatory to the firing. The water of plasticity is the amount of water needed to render the clay workable, that is, easily molded, and it is expressed in percentage of the dry weight of the clay. The untempered clay from Rivière au Vase had a range of water of plasticity from 36.6 to 39.09 per cent, which indicates a rather plastic clay. Rock-tempered samples showed only 19.2 to 22.6 per cent of water of plasticity, whereas the clay tempered with sand exhibited little decrease in water of plasticity from that of the untempered clay.

Linear-drying shrinkage is the difference between the plastic length and the dry length of the clay. The shrinkage of the untempered clay was 6.6 per cent; that of the rock-tempered clay was only 2.1 per cent. This illustrates the rôle of the rock temper in this particular clay.

### FIRING

A series of sample pellets made of clay from the site and a number of sherds from each component were fired in an electric kiln in order to learn the firing properties of both clay and sherds when fired under known conditions. With the information obtained we can compare the firing properties of clay with the sherds to discover the relationship between them.

Pellets of untempered clay, pellets with 25 per cent by weight of added rock temper, and a series of pellets with 20 per cent, by weight, of added sand were fired in the kiln. Eight sherds from the first component and four from the second component were also fired.

The pellets were heated at fifty-degree intervals from 400° to 800° C. and held at each temperature for ten minutes, until a tem-



perature of 800° C. was reached. After being heated up to 400° C. and held for the ten-minute period, one each of the untempered and the tempered pellets was taken from the kiln. At each increase of fifty degrees another set of pellets was taken out, so that, when the whole run had been fired, a complete color series from the raw clay to 800° C. had been obtained. It is quite interesting to observe the gradual change from the raw clay of a gray color to the well-fired clay, which became a light pinkish cinnamon at 800° C. It is important to note that a decided change occurs at a comparatively low temperature. At 400° C. the color of the pellets is a smoky gray; at 450° C. it changes to the reddish buff. The rock-tempered pellets seem to oxidize at a slightly lower temperature than the fine clay ones because they are more porous, and it is easier for the large quantity of organic matter in the clay to be burnt out owing to this porosity.

Eight sherds from the first component and four from the second and one of the pipestems were then fired, in accordance with the procedure of increasing the temperature by fifty-degree intervals until 800° C. was reached. All color changes, especially oxidation of the core of the sherds, were noticed, and such changes were compared carefully with the series of test pellets. The similarity in colors and color range was very striking, for the sherds from both components were almost the same as or very close to the pellets.

A color change in the sherds was noted around 450° C., when oxidation had barely started. It was clearer in some of the very coarse textured sherds of the first component than in the finer sherds, which did not show any appreciable change until 500° C. Color is a very important property of the clay, and if changes at known temperatures and time spans are observed, they are a clue to the original firing temperature used on the pottery by the Indians. Thus, from the foregoing firing tests, we are most interested in the range between 450° and 550° C. We have noticed changes at 450° C., and by 600° C. oxidation is complete. It can be said that 450° to 550° C. is a critical temperature range and that the Indian potter probably did not fire her pots much beyond this temperature, for an open wood fire cannot attain a much higher temperature. When the Indian fires her pots in an open fire in haphazard fashion, she has very little or no control over the atmosphere of her fire. The open fire cannot be spoken of as oxidizing or reducing because the

atmosphere varies from the time of starting until maximum heat is reached, and again until the heat dies down. Within the fire itself some parts might be quite smoky and others might burn efficiently, producing an oxidizing atmosphere. It is small wonder that these pots are poorly fired and have a mottled color effect. It is interesting to note that the majority of pots which appear oxidized on the surface, both inside and out, have a black or gray core signifying that the fire was not hot enough and that the pots were not left in the fire for a sufficient length of time to oxidize them throughout.

#### CONCLUSIONS

From the analysis of the Rivière au Vase sherds the most outstanding thing is the uniformity of the pottery within each of the components, borne out both by microscopic and by firing tests. The coarse grit-tempered ware is a widespread complex throughout the eastern United States, and its traits are not peculiar to this site or to this region.

Microscopic and firing tests indicate that the Indians probably used the easily worked clay at the site. Both sand and crushed rock served as tempering material. The minerals observed in studies of sand and sherds were the same not only in composition, but in size range, which indicates that sand rather than sandy clay was used as an aplastic. Very few sherds wholly devoid of temper were found, and it may be that the Indian potter did not even understand the function of the rock in her pottery. The mere fact that the grit temper complex was so widespread over a large area of the country would suggest a strong cultural tradition which would be hard to break. Perhaps they employed it for a decorative effect rather than to make the clay more easily handled, for the use of this coarse rock temper did not simplify the potter's problems. On the contrary, it is very difficult to work with such coarse-textured material.

A few conclusions can be drawn from the firing tests also. The most important fact derived from these tests is the match of the color of pellets and sherds of both components at various temperatures. This probably indicates that the pottery from both components was made from the same clay found at the site or in the neighboring area. The firing test also indicates that the pottery was probably not fired above 500° C., for this temperature compares with the maximum degree of oxidation on the surface of the pots.

One might also deduce that there was no uniform method of placing the pots in the fire, although most of them were more oxidized on the exterior surface than on the interior, but, to judge from the colors of rim sherds, it seems that the greater number of pots were fired upside down.

The potter did not exhibit any great artistic skill in manufacturing her wares, especially when the products of this site are compared with those of other centers of culture. That she did not understand or else did not care about accurate firing is evident from the study of sherd colors.

One is immediately impressed with the difference in appearance between the ware of the second or Hopewell-like component and the pottery of the first component, which is correlated with the Owasco Aspect. Chronologically, the second component is the earlier, and the pottery found was far less abundant. It is typically Woodland, and is finer and thinner than the newer ware. Firing appears to be more uniform. It is hard to explain the superiority of this pottery. The art may have held a greater interest then, and more attention may have been lavished on it, even though the pots served a utilitarian function.

It is interesting to conjecture about the fabrication of the pipe-stems. They are very different in appearance from the pottery; little or no fine temper was used. Possibly the women, who are normally the potters in a primitive society where the use of the potter's wheel is not known, were not allowed to make the pipes. It may be that, because they were the property of the men, they were made by them. This would account for the difference in manufacture.

All the materials observed in the finished product dug up by the archaeologist occur in abundance at the site, and it is reasonable to suppose that the Indians used for the manufacture of all the wares the clay at or very close to the site. Similar materials were available throughout a considerable portion of this region, and it is probable that all villages were consequently independent of one another in the matter of pottery manufacture.

#### COMPARATIVE STUDY

A brief comparison will now be made of the *Rivière au Vase* pottery with that of three other southeastern Michigan sites. Techno-

logical detail will be omitted; only significant results will be pointed out.

The first of these sites is the Younge site near Imlay City, Michigan, about thirty-five miles north of Rivière au Vase. The other two are the Wolf site, three to four miles northeast of Rivière au Vase, and the Furton site, about a mile northeast of Rivière au Vase. The technological work on the pottery from the Younge site was done by Matson.<sup>2</sup> Temper sorting under a binocular microscope was carried out on 157 sherds from the Wolf site and on 158 from the Furton. No raw clay was available for tests, but the thin-sectioned sherds, five from the Wolf site and four from the Furton, were refired.

The Younge site sherds of sandy clay are grit-tempered with rock fragments of granitic origin. The chief constituents of the tempering material are quartz, microcline and albite, biotite, hornblende, chert, and sericite.<sup>3</sup> These are the same as those found at Rivière au Vase, with the exception of the chert and a greater amount of quartz because of the sandy clay.

The chief constituents in the tempering material of the Furton and the Wolf sites are quartz, feldspars, including orthoclase and acid plagioclase, magnetite, biotite, hornblende, augite, sericite, and kaolinite. In the Furton material a considerable quantity of hornblende and augite occurs, and these minerals are easily visible without magnification. This sets the Furton pottery slightly apart from that of the other three sites. Hornblende and biotite are very prominent in the Wolf material. It is rather difficult to tell the Wolf and the Furton wares apart on the basis of material, but stylistically Greenman believes them to belong to two different archaeological phases, the Furton site being a Woodland site and the Wolf belonging to the Upper Mississippi Phase (3, p. 25). The tempering material as used in all four sites is similar; all of it is coarse and used in great abundance, some of it up to fifty per cent, by volume, of the paste.

There is not much variation in color of the fired wares from the four sites. The sherds from the Younge site range from gray shades through the orange series to pinks and reds.<sup>4</sup> Those from the Furton site are considerably darker, for some of the coloring is due to a

<sup>2</sup> See Greenman (2).

<sup>3</sup> *Ibid.*, p. 100.

<sup>4</sup> Matson, in Greenman (2, p. 104).

secondary carbon deposit accumulated through use. The range is from a cinnamon drab through a light drab to the darkest sherds, which are almost black. In the Wolf sherds the dominant colors are the drabs, hair brown, and mouse grays, with an occasional black sherd. It will be remembered that the Rivière au Vase sherds ranged from light buffs and cinnamons to the grays and blacks. The redder colors of the Youngs site are explained by Matson<sup>5</sup> as due to the presence of ferric oxide in the clay, but other than this, color is quite uniform. The majority of sherds from all sites have dark cores, which indicates a low firing temperature.

Firing tests carried out on the three sites show essentially the same results as those in the Rivière au Vase material. The sherds were heated in fifty-degree increments for ten minutes at each temperature until 800° C. was reached. In the Youngs site material Matson observes the greatest changes occurring between 500° and 600° C.<sup>6</sup> The firing of the Wolf and the Furton sherds showed that oxidation had barely started at 400° C.; all but one of the sherds was completely oxidized at 600° C., and oxidation was complete at 650° C.

The color changes in the sherds from the four sites, when fired to 800° C., all came within the range of the cinnamon colors of Ridgway. This indicates that the clay in the whole general region is much the same, all of it being a fairly widespread lake deposit.

When these four sites are considered on the basis of ceramic tests, the most outstanding thing about each one is its uniformity of ware and the absence of intrusive sherds. It is hard to state positively on the basis of ceramic analysis that a site located within a glaciated area is an entity within itself, or that there has been no trade or communication of any sort in respect to pottery. This is necessarily true because of the variety and heterogeneity of material found in a region of this sort. From the study of temper and manufacture, however, one might conclude that all four sites are separate so far as pottery making is concerned. The use of available materials has varied a little, as we have pointed out in the dominance of hornblende, augite, and biotite at two of the sites and the occurrence of more acid rock at the other two. The condition of the rock employed as temper is another indication; the rock at Wolf and Furton is far more altered than the material at Rivière au Vase.

<sup>5</sup> See Greenman (2, p. 105).

<sup>6</sup> *Ibid.*, p. 118.

The clay used at Younge, though similar in general character to that at the other three sites, is more sandy. This knowledge should be supplemented, of course, by an archaeological study of similarities and variations on the evidence of design and styles of decoration.

This study has attempted to give an objective description of the pottery from the Rivière au Vase site, and also to compare it briefly with three other sites upon which ceramic technological work has been carried out. Evidence of interchange of culture and ideas is not very strong, but undoubtedly this did occur to some extent. Naturally, the story of a whole culture cannot be built up on the evidence of the pottery alone, but, on the other hand, it must be remembered that the ceramic art is not just an entity in itself; it must be considered in relation to the culture as a whole. Ceramic technology helps to make clear this relationship, and it will prove of considerable aid to the archaeologist in the future.

UNIVERSITY OF MICHIGAN

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## RESTORATION OF FLAKES ON A QUARTZITE IMPLEMENT

MARION L. HREBEK

IN 1942, during excavations at Killarney, Ontario, under the direction of Dr. E. F. Greenman, of the University of Michigan, a large ovate blade was collected from a workshop site known as GL-1, on a former beach of Lake Huron 297 feet above its present level (4). Many of the implements and flakes, all of quartzite, are much worn on the faces and edges, a circumstance attributed to water action and indicating that they were made when the waters of Lake Huron were at the former level and when the edge of the Wisconsin glacier was within a hundred miles to the north.

The great majority of the specimens on this site are of white quartzite, but the blade under discussion (Pl. I, Figs. 1-4) is a pale green, and the presence of flakes of the same color in the immediate vicinity of the blade suggested that the original block of quartzite might easily be restored. A total of twenty-seven flakes was found, some in 1942, in the five-foot square occupied by the blade, and others in 1940, at a distance of twenty feet from the original location. In 1940 one section yielded over half of the flakes used, and most of them were picked up on the surface. All but four fit together to form the restored block.<sup>1</sup>

The blade (Figs. 1-2) is 18.4 cm. long, 8.3 cm. wide, and 5.5 cm. thick at the middle. It is not water-worn and shows no secondary flaking. There is a distinct natural cleavage line running the entire length, and from one face through to the other, and it may have been because of the likelihood of breaking that the blade was never finished. This cleavage line was evident also in the flakes and was a distinct aid in judging their positions in the restoration. The thickest portion of the blade is not in the center in relation to the width, but slightly to one side; in relation to the length the thickest

<sup>1</sup> Two other restorations of this type have to do with specimens from an Acheulean deposit at Caddington, England. See Macalister (5) and MacCurdy (6).



part is in the middle. The base, which is rounded, shows a peculiar characteristic, a flat platform that slants from the edge toward the other end at about a 45-degree angle to the long axis of the blade (Fig. 3). In the laboratory this type of platform was obtained unintentionally when the base was held nearest the body most of the time during experimental flaking of a piece of unworked quartzite collected from the neighborhood. Several other implements with thick bases from this site have the same feature.

This blade was flaked out of a larger mass of quartzite by the use of two different techniques, each of which left a distinctive type of flake scar on each face: those made by step flaking and those made by free flaking (1). The former are distinguishable in Figures 1 and 2 as dark lines running generally parallel to the long axis of the blade; the latter, which are larger, are outlined by ridges running transversely. In Figure 1 the scars caused by step flaking are on the right half of the blade, whereas those caused by free flaking are on the left half. In Figure 2, which shows the face opposite to that in Figure 1, the condition is the same. Thus the diagonally opposite half faces are alike with respect to the type of flaking. The right edge in Figure 1 has a battered appearance and is much less irregular and ragged than the opposite edge.

The flakes range in length from 4 to 9 cm.; in width, from 2.5 to 5.1 cm. None shows any sign of water action. The smallest are on the outer surface of the restored block, where they are more properly described as splinters, since there are more than two faces, and bulbs are absent. Exposure of the surface of the block to weathering, the greater force of the preliminary blows as indicated by the larger size of the percussion scars on the surface, and the coarse, loose texture of quartzite, all taken together, account for this condition. As compared to flint, quartzite has less tensile strength and the "landmarks" due to fracture are not so pronounced. Platforms are often difficult to identify since quartzite tends to break up under direct percussion and thus leaves only part of a weakly developed bulb. In the laboratory blows directed toward one spot on a block of quartzite will often detach splinters before the desired flake is removed (3).

Entire inner faces of the largest flakes do not make contact with the surface of the blade, and in the limited areas where contact is made it is always at or close to the median ridge, which is the thickest

portion of the blade. Only three flakes fit completely into scars of the blade, and only one of these extends to the edge of the blade, but it is the side of the flake that does so, since the portion bearing the platform is absent. Another of these flakes extends beyond the edge of the blade and beyond the scar into which it fits. This would contradict the conclusion, to be discussed later, that the half face on which it fits was worked before the directly opposite half face on the other side of the blade, if it were not for the fact that the upper surface of this flake is part of the outer weathered surface of the original block of quartzite. It was among the first to be struck off, and the blow must have landed at a point at least 2 cm. above the present edge and, consequently, was not recorded on that edge.

Since not all the flakes were found, the restored block is not complete, but there are two faces, and possibly a third, of the original outer surface, at right angles to one another. The largest surface of the original block is that in Figure 3, and the other face terminates at the left edge in the same view. That these are original surfaces is indicated by discoloration due to staining and weathering. The third possible face lies at the upper edge in this view, where there is a flat area 1.3 cm. long at a right angle to the other faces, and bearing percussion scars. The minimum dimensions of this original block as shown by the restoration are as follows: length, 19 cm.; width, 12 cm.; thickness, 6 cm. The cleavage line previously mentioned is visible on the face in Figure 3. There are no percussion scars on this face, but they are very evident on the side and upper surfaces.

What is probably another original surface, but not at a right angle to any other one, is shown in the upper left-hand corner of the view in Figure 4. It is a corrugated surface identical with that which is common in the quartzite hills surrounding the site. It slopes off to the point of the blade at an angle of 40 degrees to the median plane, and the corrugations extend onto the tip of the blade itself. The tip is, therefore, over part of its surface, formed by the surface of the original block. As one looks down on the restoration from the top, that is, the point end of the blade, the blade is seen to lie in such a manner with reference to the restored block that the transverse axis becomes the hypotenuse of a triangle formed by it and the two sides that meet at a right angle. In other words, the blade is in a diagonal position with reference to the block from which it was made.

The point of chief interest concerning this blade is the alternation of step flaking and free flaking. Other implements from the site exhibit this same feature. In order to obtain a step flake the blow must be struck vertically into the edge of the blade. In free flaking the blow is struck on the edge, but away from the mass of the material. If one bears this in mind and assumes that the worker was right-handed, it would seem that, after removing the preliminary flakes from the block, he held the implement in the left hand, with the point away from the body. As indicated by flake scars on the blade and by percussion scars on the flakes, the worker, beginning at the stage just previous to that represented in Figure 1, struck the right edge away from the mass of the material, that is, as if vertically down at a right angle to the plane of the face shown, and obtaining the free-flake scars that are on the half face terminating in the same edge on the opposite side of the blade (the left half face in Figure 2). The implement was then turned one quarter of the way around, right to left, and blows were delivered on and directly into the edge toward the mass of the material,<sup>2</sup> and thus the step-flake scars on the right half face in Figure 1 were obtained. Then the blade was turned half way to the left and struck again on the edge into the mass of the material, causing the step-flake scars on the right half face in Figure 2. Turning the blade finally to the right one quarter of the way, he struck away from the mass of the material, getting the free flake scars on the left half face of Figure 1. An alternative to this process would be to start on the right edge in Figure 2 and reverse the sequence. From the evidence of the flakes it cannot be said with which edge the worker started, but from the blade it can be seen which was worked last. By observing the outlines of the two edges it may be noted that one is more ragged than the other. The edge that is more even reveals the greater amount of battering; on the other this is less pronounced. In the laboratory step flaking has the effect of making the edge more even, whereas free flaking

<sup>2</sup> This method of flaking is described by Ellis (2), who terms it "percussion, direct rest edgewise on anvil." The specimen discussed in the present paper was held in the hand as it was worked, at least in the final stages, since otherwise the irregularities of the one edge (the left edge in Figure 1) would have been obliterated. Ellis states that the method of direct-edge percussion is usable "to greatest advantage in thinning down and roughing artifacts out from the raw material." He makes no mention of the step-flake scars produced by this method.

invariably leaves it ragged. This is illustrated in the difference between the two edges of the blade as shown in Figures 1 and 2. The little prominences on the right edge of Figure 2 would not have survived direct blows with a hammerstone into the edge in the same plane as the transverse axis of the illustrated blade. It was, therefore, the right edge of Figure 2 which was worked last, by hitting directly away from the mass of the material and thus forming the free-flake scars on the left half face of Figure 1. This is further correlated by the flakes which, by their positions, do show which had to be removed first.

The reduction of the original block of quartzite probably did not begin with the process of alternate free and step flaking just described, but the last stages of the work were accomplished in that manner. By this method, owing to rotation of the object from right to left, the direction of the blow and the motion of the forearm did not need to be changed. The motion of the forearm was vertically up and down, the easiest motion to use and the one by which blows can be directed with greatest accuracy and speed. The combination of this turning from right to left, or left to right, and the vertically directed blow, produced the alternate character of the four half faces of the blade.

UNIVERSITY OF MICHIGAN

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5. MACALISTER, R. A. S. 1921. *A Textbook of European Archaeology*, I: 266-269, fig. 64. Cambridge, England.
6. MACCURDY, GEORGE GRANT. 1926. *Human Origins*, I: 122, fig. 52. New York.

## EXPLANATION OF PLATE I

- FIG. 1. Quartzite blade, showing step flakes on the right half face and free flakes on the left half face. The scars caused by free flaking are larger than those made by step flaking
- FIG. 2. Reverse of the face shown in Figure 1, with step- and free-flake scars occupying the same positions with respect to the right and left sides
- FIG. 3. Flakes restored on the blade as they were in the original block of quartzite. The mottled appearance in the upper left quarter of the picture is due to weathering on the surface of the original block, of which this is the largest face in the restoration
- FIG. 4. Reverse side of Figure 3. The darker portions of the two flakes in the upper left are a weathered, corrugated surface, which also extends onto the tip of the blade itself, and is found on the semicircular flake adjacent to the right. In this view the flakes are fitted to a plaster cast of the blade



FIG. 1



FIG. 2



FIG. 3



FIG. 4

Restoration of flakes on a quartzite blade



## NUTRITION OF PALEOLITHIC MAN \*

GEORGE LECHLER

OUR interest in food, food values, and nutrition has increased considerably because of the present wartime rationing. We now realize how much of our daily life is centered around the problem of getting something to eat. Although it is obvious that the matter of securing food has always been a pressing one, surprisingly little attention has been paid to the history of nutrition. Thus physicians, even stomach specialists, have no definite information on this subject. What did man eat in the past, when serious ailments and diseases such as allergies, stomach ulcers, and diabetes were much less common?

Much of the food of previous centuries was affected by processes of fermentation. This means that there was a great deal of sour food, which was richer in vitamins because of the presence of the fungi of fermentation. The trend to the domination of sweet food began less than one hundred and fifty years ago. The consumption of cane sugar came with the opening of the trade routes to the East Indies and has grown steadily since. But my grandmother, like all the other housewives of the rich farming country in Germany, kept sugar locked in a sugar box and never allowed the key to go out of

\* I wish to thank Mr. Volney H. Jones, associate curator, Division of Ethnology, Museum of Anthropology, University of Michigan, for his kindness in checking the technical botanical terms used in this paper. He referred me to the following literature for general orientation:

Campbell, Harry, "The Evolution of Man's Diet," *The Lancet*, 2 (1904): 781-784, 848-851, 909-912, 967-969, 1097-1099, 1234-1237, 1368-1370, 1519-1522, 1667-1670.

Furnas, C. C. and S. M., *Man, Bread and Destiny*. New York, 1937.

Graubard, Mark, *Man's Food, Its Rhyme or Reason*. New York, 1943.

Soyer, A., *The Pantropheon; or, History of Food, and Its Preparation, from the Earliest Ages of the World*. London, 1853.

Unger, Frans, "On the Principal Plants Used as Food by Man," *The Executive Documents*, Printed by Order of the Senate of the United States, First Session of the Thirty-sixth Congress, 1859-60, VI: 290-332. Patent Office Report (Agriculture). This work was first published in Vienna in 1857. It was translated especially for this Report.



her possession. Before the introduction of cane or beet sugar, honey was the only considerable supply of sweet food in Europe, and the hunting of it was such good business that in the forest districts of East Prussia, Lithuania, and Poland collectors of wild honey represented a special profession. A minor source of sweetening was syrup of carrots; syrup from maple and birch trees was used still less frequently. However, the quantity of sweet food available was so small compared to what we have today that such food was the exception rather than the rule. This change to the use of sugar explains the tremendous increase of dental caries since prehistoric times.<sup>1</sup>

Let us consider man as he lived 50,000 to 100,000 years ago. The first advance of the Wurm or Wisconsin glaciation, which was the last of the four of the Pleistocene, started around 110,000 B.C.<sup>2</sup> *Homo sapiens*, the modern type of man, appeared then all over Europe, northern Africa, and Asia. What sort of food did he eat? Excavation of rock shelters containing many bones from animals which had been eaten by man<sup>3</sup> convinced scientists of forty years ago that Ice Age man was merely a hunter. Since investigators found no traces of vegetable foods in the remains, they overlooked the possibility that ancient man had vegetables in his diet. A study of comparative ethnology, however, and research among modern primitive tribes living under arctic conditions similar to those of the Ice Age may help to solve the problem. The information we have concerning the eating habits of the lake dwellers of Europe (3,000–2,000 B.C.) and other generally observed basic facts may also be of assistance.<sup>4</sup>

Food collecting was more important to Old Stone Age man than

<sup>1</sup> I am indebted to Dr. Edward Freimuth, Detroit dentist, who informed me about the research done at the University of Michigan. Dr. Kenneth Easlick, School of Dentistry, University of Michigan, was kind enough to send me a reprint of an article in which the definitely established evidence is summarized. Jay, Philip, and Bunting, R. W., "The Relation of Carbohydrate to Lactobacillus Acidophilus and Dental Caries," *Proceedings of the Sixth Pacific Science Congress, held at Berkeley, Stanford, and San Francisco, July 24 to August 12, 1939*, VI: 613–619.

<sup>2</sup> Milankovitch, Milutin, *Ein neues Kapitel der exakten Wissenschaften und dessen Anwendung in den beschreibenden Naturwissenschaften*. Belgrade, 1937. Idem, *Mathematische Klimalehre und astronomische Theorie der Klimaschwankungen*. Belgrade, 1930.

<sup>3</sup> Obermaier, Hugo, *Der Mensch der Vorzeit*, 2 vols. Munich, 1912.

<sup>4</sup> Hahn, I., "Die Auswahl der zur Dauernahrung genutzten Pflanzen," *Sitzungsberichte der Gesellschaft naturforschender Freunde*. Berlin, 1934.

hunting was. Women and children could gather plants practically every day during the warmer period but, although the men were hunting during this time, they were not always certain to return with game. Cave paintings, the main purpose of which was hunting magic, show what difficulties the hunters met in killing their prey. Most of these pictures are in nearly inaccessible places; subterranean rivers must be crossed and chimney-like shafts passed to reach them. Sometimes these spots are 3,000 feet from the entrance of the cave, an indication that artificial light must have been needed to paint the pictures. Sticks of wood or fagots or crude oil lamps must have been used. Evidently magic was supposed to be necessary to secure success in hunting; in other words, the hunters often failed.

An analysis of the meat diet of early man indicates that he preferred the larger game, such as mammoth, rhinoceros, wild cattle, bison, horse, and bear. During the second half of the Magdalenian period reindeer seems to have been his main food. The broken skullcaps prove that he must have eaten the internal parts, such as brains, and the so-called "bone buttons,"<sup>5</sup> which are short pieces of bone tubes, are evidence that he broke the tubes to extract the marrow. From observation of the customs of primitive natives we may conclude that he drank the blood of animals and ate such organs as the kidneys, lungs, and liver. The Australians have a custom of throwing kangaroos into a fire and waiting until the belly is expanded under the heat, whereupon they open it up and devour the intestinal parts. Perhaps, in similar fashion, ancient man ate the half-digested stomach contents of game.<sup>6</sup>

Some of the Magdalenian sites of about 20,000 B.C., which are near Ahrensburg and Meiendorf, north of Hamburg, were only ten miles from the edge of the ice sheet, so that the climatic conditions were the same as those in the northernmost part of Siberia.<sup>7</sup> In Siberia, too, reindeer constitutes the chief food, and the Siberians and Lapps depend upon the stomach contents of this animal for

<sup>5</sup> Schmidt, Alfred, "Über die Entstehung sog. 'Knöpfe' in altsteinzeitlichen Fundschichten," *Mannus, Zeitschrift für deutsche Vorgeschichte*, 26 (1934): 204-211.

<sup>6</sup> Klaatsch, H., Andree, J., Weinert, H., Lechler, G., *Das Werden der Menschheit*. Berlin, 1936.

<sup>7</sup> Rust, Alfred, *Vor 20,000 Jahren, eiszeitliche Rentierjäger in Meiendorf, Holstein*. Neumünster, 1937. *Idem*, *Das altsteinzeitliche Rentierjägerlager Meiendorf*. Neumünster, 1937.

their supply of vegetables. Reindeer feed on lichens, which are richer in vitamins and iodine than most of our vegetables. The half-digested sour mash in reindeer stomachs is essential to these northern hunters as a preventive of scurvy. No other vegetables are available in northernmost Siberia, and, likewise, there was no edible plant life in Ahrensburg during Pleistocene times, with the exception of mosses. Mosses are important in the diet of Siberian natives, and they were used for food in northern Europe also.<sup>8</sup>

With the aid of evidence afforded by the broken-bone relics of the Ahrensburg site let us reconstruct the butchering of a reindeer according to the procedure of primitive northern tribes. As soon as a reindeer was killed, the antlers were probably broken from the roof of the skull by means of a heavy stone. They were exceedingly valuable because various kinds of tools and weapons could be carved from them. Next, the brain was removed to a bladder bag to be served as a particular delicacy. After that the animal was skinned. The main attraction — and this cannot be overemphasized — was the stomach filled with vegetables, arctic plants which would not be digestible for man without predigestion by the reindeer. Lungs and liver were cut into small pieces, placed in a leather sack, and mixed with fatty substances from the abdomen. All the blood was added to this, and the mixture, a blood pudding, was heated later over the fire. The heart was roasted on a spit, and the rest of the meat was cut into strips and hung on birch rods to be dried or grilled. The bones containing marrow were also removed. A festival dinner would consist of marrow from the bones, "stomach spinach," and brain. The skull, as a priceless delicacy, went to the actual killer. All of it was extremely desirable, including the parts inside the nose, the tongue, the larynx, the meat from the cheeks, the eyes, and the nerves from the inside of the jaws. The spinal cord was pushed out of the vertebrae with a thin rod; the feet were dissected and the bones of the toes broken to obtain the marrow, perhaps in the way we eat lobster today.

The largest slaughterhouse of mammoths ever uncovered was at Predmost, in Moravia, not far from Brno, the city which gave its name to the Bren gun.<sup>9</sup> Fifteen hundred mammoth skeletons were

<sup>8</sup> Smith, J., *A Dictionary of Popular Plants*, p. 92. London, 1882.

<sup>9</sup> The English made "Bren" out of "Brno," but on many maps the name appears as "Brünn."

counted there.<sup>10</sup> The bones were nicely assorted — one pile each of hip bones, shoulder blades, and others. Evidently hordes of people met at this spot to celebrate their greatest feast. A similar site was found in France, near Solutré,<sup>11</sup> where about 200,000 horses had been killed by being chased over a precipice at the end of a slanting plateau. I may mention, incidentally, that the same method of hunting was not unknown in this country (see Fig. 1), where it was

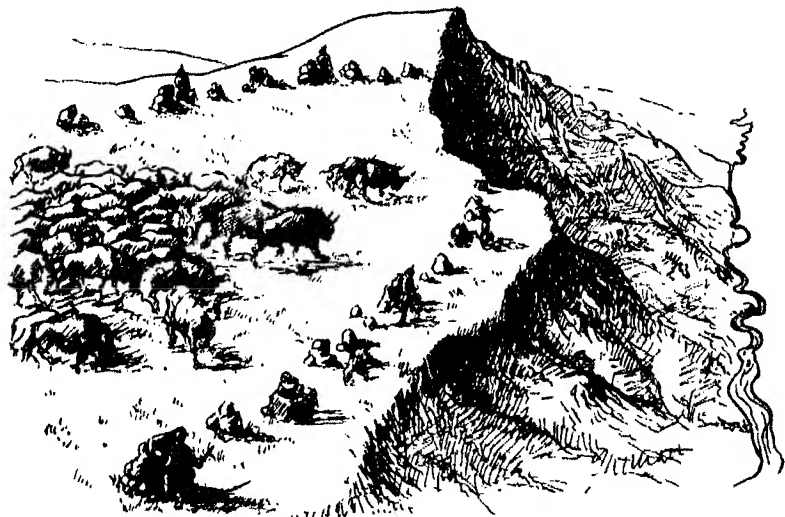


FIG. 1. A newly found buffalo fall in Montana, shown as used by the Amerindians. Hunting in this way was practiced in the Upper Paleolithic

practiced along the slopes of the Rockies.<sup>12</sup> Since this kind of hunting needed the coöperation of groups larger than those which normally populated a rock shelter, it is probable that Solutré was also a festival meeting place.

<sup>10</sup> Absolon, Karl, "Predmost," *Acta Musei Moraviensis*. Brno, 1926-32.

<sup>11</sup> Sollas, W. J., *Ancient Hunters and Their Modern Representatives*. London, 1911.

<sup>12</sup> I got detailed information on a newly found buffalo fall (Fig. 1) which was discovered by a former conservation officer, Robert H. Fletcher, Butte, Montana. This hunting practice is described by William T. Hornaday in "The Extirpation of the American Bison," *Annual Report of the Regents of the Smithsonian Institution for 1887*, Part II (1889): 483-484. A very excellent colored painting showing such a buffalo hunt may be found in the *National Geographic Magazine*, 86 (1944), Plate II (after p. 80).

Life must have been relatively stationary, even though the camp was moved farther north in the summer in order to follow the reindeer which, like migratory birds, range northward during the warm weather. Storing meat for the winter was not difficult. Very likely it was put into a pit, which was covered with heavy stones to protect it from beasts of prey. The nomadic way of living during the Old Stone Age has always been stressed too much. In order to stay through the winter in a rock shelter, and to keep fires burning on a twenty-four-hour schedule, it was necessary to store large piles of wood. Food, too, had to be put aside. Ahrensburg and Meiendorf, where many reindeer calves were killed, were undoubtedly summer camps.<sup>13</sup> The winter camp for these groups must have been in Thuringia, 250 miles south, where contemporary sites have been found. In addition to reindeer, small game was common around the southern camps. There is evidence that many birds, from the white grouse to the swan, and such rodents as the Obi lemming and the marmot were hunted, and that all the members of the stag family were favored as food.

If we recall that pre-man was a plant eater, we are fairly well justified in believing that man during the Old Stone Age also had some vegetables in his diet. Plant collecting was carried on not only to secure a daily food supply but to store food away for the future. We may conclude that this was done because anthropoid apes prepare plants for later use.<sup>14</sup> Orangutan females gather *Amomum cardamomum*, a spicy plant known to medicine for its stimulating effect, pile up the leaves, and cover them with dirt. After some weeks the whole group returns to the place, and the males dig up the leaves, which have fermented, and eat them. They behave in a very gay and noisy fashion, probably because of the stimulating effect of the plant itself as well as the alcohol, which is a by-product of the fermentation. The presence of *Amomum cardamomum* in the stomachs of killed gorillas indicates that they may have the same habit as the orangutans.

A study of the life of primitive natives shows that the women are constantly occupied with plant processing. The most striking

<sup>13</sup> List given by Rust, *op. cit.*, p. 88: 32 old reindeer, 22 young ones, 17 calves of the first summer, 1 horse, 1 badger, 1 fox, 1 wolverine, 2 hares, 1 mygale, 6 geese, 5 ducks, 6 swans, 1 crane, 1 spotted rail, 1 sea gull, 6 mew hens.

<sup>14</sup> Reichenow, Eduard, *Sitzungsberichte der naturforschenden Gesellschaft*, p. 8. Berlin, 1919. *Idem*, *Archiv für Protistenkunde*, 41 (1920): 2-4. Jena.

thing of all is that these people seem to prefer plants which have a bitter taste or are even poisonous when raw.<sup>15</sup> After the leaves have been fermented in pits they become tasty and nourishing food.<sup>16</sup> This pit processing is so common that we may call it a cradle trait of human culture. We have traces of that procedure even in modern European diet. Sauerkraut, for instance, was formerly fermented in pits, and in some parts of Europe was processed in this way until the last century. The barrel for sauerkraut originated from the lining of wooden boards which was placed in the pit to avoid waste — in other words, the barrel is a pit taken out of the ground.

Although plants are not the same in all parts of the world, this treatment of them has been universally employed. The Australian natives, for example, gather bulbs of the *Dioscoreaceae*, the yam family, soak them in water, leave them in a pit for several weeks, again soak them, and, after they are dried, crush them into flour with stones. The flour is then kept as a staple food. The tribesmen in Malaya squeeze the juice from *Dioscorea daemona*, thicken it, and make arrow poison of it.<sup>17</sup> The slices of the bulbs are then prepared as food in the Australian way. The Javanese pour juice from *Dioscorea hirsuta* into the water for the purpose of poisoning fish.<sup>18</sup> They also use the bulbs of these plants for food. There are many other examples of food plants, but an outstanding one is the American manioc or cassava, *Manihot utilissima*. This was grated by the Indians, who then squeezed the juice out through bags. They utilized the juice, which contains prussic acid, as a meat preservative. Putting the meat in the juice prevented putrefaction and made preservation possible for months.<sup>19</sup> The grated manioc was fermented in a pit, later rinsed in water, and then allowed to dry. It represented their most important food. We have indications that such processes existed in Europe also, for there are survivals of them. We may mention that *Arum maculatum*, a plant

<sup>15</sup> Crawford, John, "On the Vegetable and Animal Food of the Natives of Australia in Reference to Social Position, with a Comparison between the Australians and Some Other Races of Man," *Transactions of the Ethnological Society of London*, 6 (1868): 112-122.

<sup>16</sup> *Zeitschrift für Ethnologie*, pp. 245-259. *Verhandlungen der botanischen Vereine der Provinz Brandenburg*, 54 (1932).

<sup>17</sup> Levin, S., *Naturwissenschaftliche Wochenschrift*, 10 (1895): 209.

<sup>18</sup> Vaughan, Stevens, *Veröffentlichungen des königlichen Museums*, 2 (1892): 110.

<sup>19</sup> Nordenskiöld, E., *Modifications in Indian Culture*. Gothenburg, 1930.

which occurs in Europe, belongs to the taro family, which is well known in America and is important in the South Seas, where it is one of the essential foods. If a person bites into taro in the raw, unprocessed condition, his mouth will be swollen and sore for two weeks. The taro plant of Europe was used for toothache in medieval times, and morsels placed in the cavities of a tooth were considered very effective in relieving pain. The root of this plant was likewise processed for food.

Primitive food conditions are reflected in the Bible, where it is stated that grass seeds and leaves from trees were used for nutrition. As an illustration of that primitive situation we may mention the aboriginal cultural groups in California and Nevada known as "seed gatherers." Plant relics found in the lake dwellings of Europe give us a complete understanding of the plants used at that time and reveal something of the beginnings of agriculture. Edward Hahn and his sister Ida, who did much research concerning nutrition in the past, also found out many things about the origin of agriculture and animal breeding,<sup>20</sup> and the discoveries in the lake dwellings made since Hahn's death confirm the validity of his work.

Tasty edible plants were not domesticated at first; they remained in their wild condition, but those that required fermentation or other processing were protected and domesticated. An analysis of the lake-dwelling site at Sipplingen<sup>21</sup> corroborates this suggestion. The strata of the settlement contained among the kitchen refuse remains of the following vegetation: 12 cultivated plants; 17 associated plants (then cultivated); 22 weeds; 37 forest plants; 67 water plants; 25 plants from meadows; 13 plants of different habitat. This makes a total of 193 plants, a few of which might have been used for medicinal purposes, such as *Verbena officinalis*, or holy herb, *Saponaria officinalis*, or soapwort, *Malva silvestris*, or common mallow, and *Atropa belladonna*, or dwale, deadly nightshade. Although we believe we enjoy the widest possible variation in food,

<sup>20</sup> Hahn, Edward, *Die Haustiere und ihre Beziehungen zum Menschen*. Leipzig, 1896. *Idem*, *Demeter und Baubo*. Lübeck, 1896. *Idem*, *Das Alter der wirtschaftlichen Kultur der Menschheit*. Heidelberg, 1905. *Idem*, *Die Entstehung der wirtschaftlichen Arbeit*. Heidelberg, 1908. *Idem*, *Die Entstehung der Pflugkultur*. Heidelberg, 1904.

<sup>21</sup> Reinerth, Hans, *Das Pfahldorf Sipplingen*. Leipzig, 1938. Bertsch, Karl, "Palaeobotanische Monographie des Federseerieds," *Bibliotheca Botanica*, No. 105 (1931). Bertsch, Franz, "Herkunft und Entstehung unserer Getreide," *Mannus, Zeitschrift für deutsche Vorgeschichte*, 31 (1939): 171-183. Leipzig.

we shall see that primitive man had a broad selection if we examine the list of plants from Sipplingen.<sup>22</sup> The twelve cultivated plants include three kinds of wheat, oats, two kinds of millet, peas, poppy, parsley, flax, apple, and plum. From other lake-dwelling sites we know, in addition, lentils and pears. Poppy and flax seeds were used for oil production. Apples were sliced, dried, and strung. The seventeen associated plants represent the species which had been cultivated in the past, but which had remained associated with cultivated plants since their own cultivation had been abandoned. The best example of such a plant is Good-King-Henry (*Chenopodium Bonus-Henricus*), which was eaten as spinach before the Mohammedans brought the modern species of spinach to Europe. Good-King-Henry was cultivated in the East Indies until the present century.<sup>23</sup> Prickly lettuce and land lettuce are still grown in some remote areas, and bacon weed, or atriplex, known as food even to the Pennsylvania Dutch, was widely used by the lake dwellers.<sup>24</sup> Polygonaceae, or knotweeds, the seeds of which produce a very white flour, were cultivated in eastern Germany and Poland until the nineteenth century. Although dog's parsley is considered a deadly poison, it must have been cultivated and frequently eaten, since it was found in thirty-three pots excavated at the lake-dwelling site at the Alpenquai, Zürich.<sup>25</sup> A whole vessel full of *Galeopsis Tetrahit*, ironwort or hemp nettle, was found, and it is thought that this plant may have yielded oil. In all the lake-dwelling sites the largest amount of seeds was from berries of the black nightshade, another plant regarded as poisonous. We know, however, from Euricius Cordus, who died in 1535, that it was cultivated as a vegetable and that its berries were eaten as a dessert.

Among the twenty-two weeds most frequently used were starwort, nipplewort (*Lapsana communis*), and stinging nettle, which was eaten like spinach. The most important of the thirty-seven forest plants were: acorn, beechnut, hazelnut, bird cherry, haws of white-

<sup>22</sup> Maurizio, Adam, *Die Geschichte unserer Pflanzennahrung von den Urzeiten bis zur Gegenwart* (deals with 621 plants). Berlin, 1927.

<sup>23</sup> Bertsch, K., in Reinert, *op. cit.*, p. 106.

<sup>24</sup> How much this tradition is still alive can be concluded from the fact that a twenty-year-old student of mine, Mr. Mark Shaffer, 4024 Clements Avenue, Detroit, who is of Pennsylvania Dutch descent, knows the use by personal experience.

<sup>25</sup> Bertsch, K., in Reinert, *op. cit.*, p. 107.



thorn or Maythorn, plums from sloebushes or blackthorn, berries of the cornelian tree often called dogwood, rosehaws, elderberries, and blackberries; black and red raspberries and strawberries were also common, as well as bittersweet nightshade, still another plant believed to be poisonous.

The 105 plants comprising the last three groups are not in use at all today, but they indicate the amount of plant material gathered in the Old Stone Age. It is safe to suppose that the leaves of many herbs of the family Cruciferae such as cress, nasturtium, mustard, rape, gold-of-pleasure (or oil weed), and all kinds of brassica, from which cabbages have been developed, were fermented in pits. The fermented food was the forerunner of sauerkraut, which was later made of cabbage alone, but the name still refers to herbs in general. The facts that cabbage has a bad odor when cooking and that some kinds can be eaten only after they are sweetened by frost suggest that in earlier days processing was necessary in order to make this vegetable at all edible. It is certain that sauerkraut making was carried on long before the beginning of plant cultivation. In cold areas the fermenting pit could be replaced by sacks of animal skin hung close to the fire to prevent freezing, a method used by Algonquins.

Botanists agree that most of the plants from which our garden vegetables are derived are not edible at all, and that sometimes the character of the plants has been changed through crossbreeding. An example of such a change is the carrot. The wild carrot, *Daucus Carota*, has a fibrous, woody root. The giant wild carrot, *Daucus maximus*, from upper Italy, was crossed with it, and the result was a hybrid with a sweet fleshy root, our carrot, *Daucus sativa*. This crossbreeding took place in the New Stone Age.<sup>28</sup>

Starchy food was produced from wild-grass seeds collected in bags. Spoilage was prevented by keeping the seeds in the bags and roasting them by dropping hot stones on them. This was probably done as early as the Old Stone Age. During the second half of the Magdalenian an increased interest in plants is indicated by the appearance of carvings and pictures of them among the art objects. Up to that time only animals had served as subjects for such decorations. Relics from the lake dwellings and other neolithic sites prove that cultivated grain was still parched at that time — perhaps be-

<sup>28</sup> Bertsch, K., in Reinerth, *op. cit.*, p. 107.

cause this method was the traditional way. The kernels which are found are all charred, apparently because the women burned the grain by mistake while parching it. Until a century ago it was the custom to parch grain in this way in the Hebrides, Orkneys, and Faroes.<sup>27</sup>

There is considerable evidence that wild-grass seed and primitive grain needed treatment to make them pleasant to the taste. Millet of today still has a disagreeable taste, which it loses only after being cooked, mashed, and scalded several times.<sup>28</sup> It was very important as a food in Europe and is still the chief grain of Africa. Some types of wheat, too, such as *Triticum monococcum*, must be scalded after the dough is kneaded in order to remove the bitterness.<sup>29</sup> This type of wheat passed out of use in Europe when American wheat, which has more gluten than any European wheat except spelt and which is consequently more suitable for baking, began to be imported. The necessity for removing the unpleasant taste explains why fermentation of wild-grass seed and grain was practiced. We call such a process "brewing." Beer, therefore, is not an invention of a late cultural stage, but marks the beginning of agriculture and was originally simply a method of making wild-grass seed edible. Men liked the stimulus given by the alcohol and urged the women to make more. The women knew the places where the best grass seeds grew, and such areas were protected.

Another proof that brewing or beerlike fermentation is a very old process is the custom, formerly world-wide, of chewing food and spitting it into vessels to ferment, in order to make it into a tasty beverage. This habit has been so generally observed that it, too, is considered a cradle trait. Some of the beverages obtained as products of such fermentation are kawa, in the South Seas; pulque, in Mexico; manioc, in South America; soma, in the East Indies; nectar, in ancient Greece; and mead, among the heroes of the Teutonic Edda. The other method of fermenting grain is to let the dough turn sour; the use of leaven in baking bread is a survival of that custom. Flummery, a sweet food of today, was in the past

<sup>27</sup> Demeter, Karl Joseph, *Monatsschrift für biologisch-dynamische Wirtschaftsweise*, 11 (1936): 134.

<sup>28</sup> Edward Hahn used to invite his students to his home, where his sister Ida served mash or grit of millet. Everybody had to taste first the bitter unscalded mash.

<sup>29</sup> Hahn, *op. cit.*, p. 273.

a mash of oatmeal allowed to turn sour and was very common in Europe. The water was squeezed out of the mash through a bag and then the mixture was cooked with milk. This food was eaten daily by the Welsh people,<sup>20</sup> and a similar mash made of barley was common in Poland, Lithuania, and Estonia and was called *kisl*.<sup>21</sup>

With the development of hafted tools in the Middle Stone Age after 12,000 B.C. the protection of plants made another stride forward. The soil was loosened with hoes and weeds were removed, so that seeds became larger and better. The choice seeds were selected for reseeding; agriculture was on its way.

From the different processes described we may get at least a few hints of the devious means by which man of the Old Stone Age groped his way toward the agricultural stage. No immediate thought of usefulness but incidental observations or the desire for some stimulation actuated him. He had applied magic for hunting; then as plants became more important in his economy he transferred magic into the realm of agriculture. This he did primarily because he felt his own inadequacy more than before as he became dependent upon the seasons and upon planning all year round; a calendar based on astronomy became necessary, and it in turn revealed to him the cosmic order and induced him to aspire to higher religious levels.

WAYNE UNIVERSITY  
DETROIT, MICHIGAN

<sup>20</sup> Rhys, Sir John, and Brynmor-Jones, David, *The Welsh People*, p. 563. London, 1900.

<sup>21</sup> *Mitauer Kochbuch*, VI (1876): 44. Mitau. Maurizio, Adam, *Die Getreide-nahrung im Wandel der Zeiten*, p. 125. Zürich, 1916.

## AN INDIAN VILLAGE IN THE LITTLE CAYUSE MOUNTAINS OF MONTANA

WILLIAM MULLOY

**I**N THE course of reconnaissance investigations in various parts of eastern Montana during 1940 and 1941 by the Montana Archaeological Survey<sup>1</sup> there were discovered a number of small villages and isolated house sites, of a type that seems not to have been described hitherto in the literature. Their uniformly un-stylized nature, as well as the lack of ethnological information readily available concerning them, makes their cultural associations obscure. The appearance of the structures and the associated artifacts suggest, however, that they belong principally to an early historic period, though a few may date from a late prehistoric one.

The present report is a brief preliminary description of certain of the manifestations, together with a few remarks on their probable cultural relationships. A detailed examination of all the material and a discussion of its significance will have to await a more extended examination of the literature. A study of the accounts of early contemporary observers and a thorough interrogation of representatives of the modern Indian groups in the area will probably provide much additional information.

Villages and house sites of the type to be described are known to the writer only in eastern Montana and northern Wyoming, but it is not inferred that they are limited to this area.<sup>2</sup> Much of this territory has not been investigated in detail, and since the

<sup>1</sup> The Montana Archaeological Survey was a research project of the Works Projects Administration of Montana sponsored by Montana State University (O.P. 165-1-91-189, W.P. 3450).

<sup>2</sup> The discovery of most of these sites would have been impossible without the aid of Mr. Oscar T. Lewis, Montana Archaeological Survey field supervisor, whose detailed knowledge of the country, born of long residence in it, was essential. He had known of certain sites for many years and was responsible for finding others. For the location of the Little Cayuse Mountain site the writer is indebted to Miss Patricia Wyn, on whose father's ranch it lies. The Pompey's Pillar Cuesta site was first noted by Mr. John Nelson of Billings, and Mr. Big Sheep of Lodge Grass first called attention to the Big Horn Mountain site. The writer deeply appreciates the cooperation of all these people.

villages usually occur in isolated and well-hidden spots, such examination will probably turn up many more examples.

At present three villages and three isolated house sites have been observed. The largest village, which includes six house sites and one small structure of doubtful function, is located on Thirty Mile Mesa, several miles east of the old Thirty Mile Stage House on Highway 87, about thirty miles north of Billings. Another group of six house sites and two structures, likewise of doubtful purpose, lies on Pompey's Pillar Cuesta, near Pompey's Pillar Creek and about fifteen miles above its mouth. This creek is an intermittent northern tributary of the Yellowstone River, which it enters about three miles above Pompey's Pillar. The third village of three house sites, here described in detail, is in the Little Cayuse Mountains in northeastern Sweet Grass County.

Another isolated house site high in the Big Horn Mountains is near Tipi Pole Spring, which is the source of Lodge Grass Creek. Two additional ones were noted on upper Razor Creek, about twenty-five miles north of Billings.

#### THE VILLAGE IN THE LITTLE CAYUSE MOUNTAINS

A detailed description of all the manifestations observed is not possible in a short account, but this village may be regarded as fairly typical of most of the others. The two most frequent types of construction are found here, although the structures were not very well preserved.

The Little Cayuse Mountains are east of Melville, which is in north-central Sweet Grass County. They do not represent an extensive uplift, but are formed by the erosion of massive horizontal sandstone members by various tributaries of the Musselshell River. This action has produced a large, much-intersected area of rugged country. A prominent geographical feature is a broad valley known as "Googler's Basin." It is bounded to the east and west by steep sandstone slopes and escarpments, which are covered in most places with a forest of small pine trees.

At the western periphery of Googler's Basin is a steep elevation which forms its boundary. This series of escarpments and steep talus slopes is heavily wooded and is characteristic of the usual topography of the area. The talus slopes attain a height of more

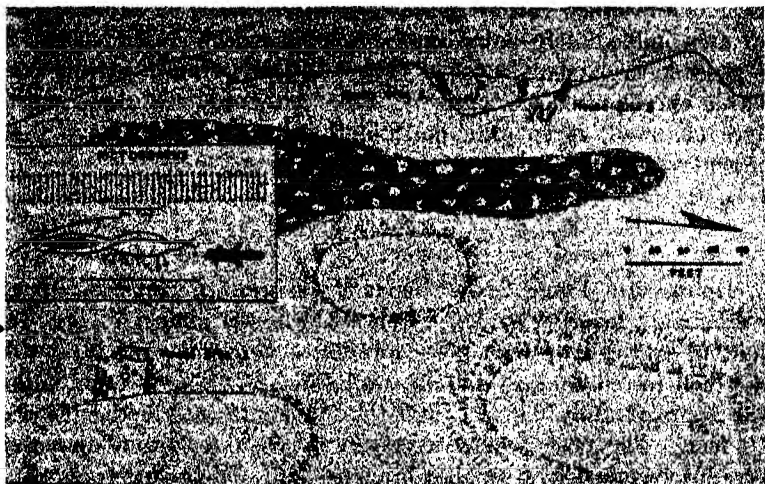


FIG. 1. Map of the village in the Little Cayuse Mountains

than three hundred feet. In a location about two miles to the northwest of the Wyn ranch house, and midway between the top and the bottom of a slope, a large slab of rock has split away from the side of a cliff, leaving an extensive crack running parallel to the face of the slope. Talus débris has filled this crack and erosion has cut away much rock, so that the area now appears as an irregular depression some four hundred feet long and over one hundred feet wide. To the west stands a cliff over fifty feet in height; several large eroded remnants of the split-off portion project to the east (Fig. 1).

The enclosed area is irregular, but is uniformly depressed and provides an excellent shelter. Here a small village was situated, of which three log lodges in various states of disrepair and several pictographs on the cliff walls remain. The location was well selected, since it affords both shelter and concealment. One might pass many times within a short distance of it and not become aware of its existence. As a defensive site its position is poor. It would be especially vulnerable to attack from the cliff above. Parts of the depression were very swampy and might have served as a water supply at most seasons. There are, however, a number of excellent springs on the flat directly below the slope. In common with

most of the other villages of like type this one is so situated that an area immediately adjacent to it commands a broad vista. It is possible to overlook most of Googler's Basin from a jutting crag within one hundred feet of the village. Although only three houses were observed, it is quite possible that others might have been present formerly.

#### HOUSE SITES

##### *Site 1*

House sites 1 and 2 were against the western cliff beneath an overhanging ledge (Fig. 1). Site 1, which was almost intact, was built of vertically placed poles forming a hemicone, the open side of which rested against the cliff wall (Fig. 2). The interior radius was approximately 6.9 feet, and the maximum interior height was 6.0 feet. The poles, which averaged 0.5 to 0.8 foot in diameter, were interspersed with smaller branches and odd broken fragments. None of the poles showed marks of cutting or trimming, but, as in the other structures, odd dead branches picked up in the woods seemed to have been used with little or no working. The construction was based on several logs laid against the cliff to form the skeleton of the hemicone, after which smaller branches and odd broken fragments were used to fill the interstices. About the outside were placed tabular sandstone slabs, which covered the surface to a height of about three feet. At the north intersection of the wall with the cliff a gap about two feet wide formed the door.

The structure rested partly upon rock and partly upon soft, sandy soil. There was no evidence of a fire inside the house, although a small amount of ash suggested that there may have been a small cooking fire just outside the door.

##### *Site 2*

Directly to the north of house site 1, and under the same ledge, house site 2 was located, but it was only partly protected by the overhanging cliff (Figs. 1-2). It too was about seven feet in diameter and was probably hemiconical, although its poor state of preservation prevented an exact description of it. Only an irregular pile of slabs partly outlining the periphery remained. A few poles lay on the slope in front of the ruins. The house appeared to have been destroyed intentionally, for the slabs were pushed away and



FIG. 2. House sites 1 and 2. Construction type A1

the poles thrown back, perhaps to obtain material for the construction of site 1, since some of the material had disappeared. The floor was more clearly defined than in site 1, being composed of hard-packed earth under 0.3 foot of fill. There was no fireplace. The appearance of the floor and the slabs indicated that this door may have been to the east.

### *Site 3*

This dwelling was built against the west side of a projecting erosion remnant some fifteen feet high, which constituted a part of the eastern side of the depression. It appeared to have been roughly rectangular, approximately sixteen feet in north-south diameter and fourteen feet from east to west. The east side was formed by the almost perpendicular face of the cliff; a portion of the west wall consisted of a smaller erosion remnant (Figs. 1, 3). The other walls were outlined by tabular sandstone slabs lying in disarray and by a few irregular fragments of logs. The original shape would be extremely doubtful if it were not possible to compare it with almost identical structures on Thirty Mile Mesa and Razor Creek, which were much better preserved. These suggest that the walls were originally an irregular cribwork of logs placed one on



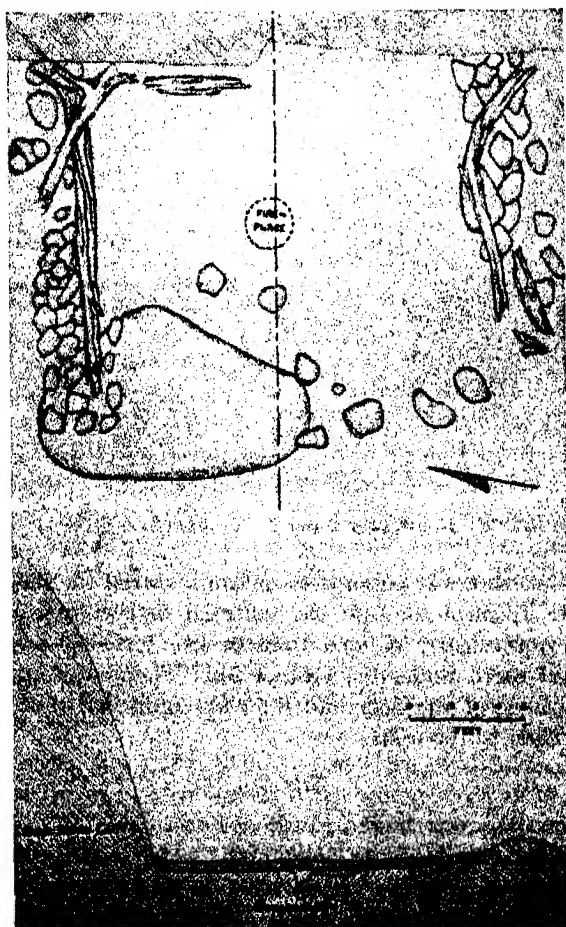


FIG. 3. House site 3. Construction type B1

top of another in an ingenious though unstylized fashion. The appearance of the walls was probably similar to that of the walls in the Big Horn Mountain house shown in Figure 4. The stone slabs, few of which remained in place, were employed in a manner similar to that in sites 1 and 2. There were no marks of cutting or trimming on any of the logs.

The well-defined, hard-packed dirt floor was covered with



FIG. 4. The house in the Big Horn Mountains. Construction type *B2*

0.8 foot of débris composed principally of leaf mold and pine needles intermixed with stones. The centrally located circular firepit was 0.4 foot in depth and 2.4 feet in diameter. Two small stone slabs rested on the floor. The poorly preserved walls made the position of the door doubtful. If a lateral door existed at all, it was probably somewhere in the western wall.

Only one indication of historical associations was found — a large tree growing out of the cliff directly above the structure. From it projected the stumps of three branches that had been laboriously cut off, apparently with a metal knife. Their appearance suggested that they had been cut while alive.

#### PICTOGRAPHS

The pictographs illustrated in Figure 1 were discovered under a second overhanging ledge in the eastern cliff. The outlined animal figure was red; the others were black.

#### THE BIG HORN MOUNTAIN SITE

In order better to illustrate the cribbed type of construction represented by house site 2 a somewhat similar isolated house from

the vicinity of Tipi Pole Spring, at the source of Lodge Grass Creek in the Big Horn Mountains, is described. It is about one-half mile east of the spring in a wooded area about one hundred feet from the edge of a cliff overlooking a deep gorge.

The house was completely isolated, and was the only cultural manifestation discovered in the area other than a modern Crow camp near the springs. It was a pentagonal structure of horizontally laid logs that interlocked at the five corners. The large logs averaged eight to twelve inches in diameter, and a number of small branches filled the interstices. They looked like the logs that might have been gathered in abundance from the surrounding woods, and they might have been long dead when used, for they bore no evidence of cutting. Most had been prepared by breaking off the lateral branches. About the outside of the irregularly laid log wall were placed vertical stone slabs (Fig. 4), but there was no door. When observed, the logs that remained reached a height of four and one-half feet, but no roof fragments were left in place. The maximum diameter of the enclosure was twenty-one feet. The house rested on rock, which was covered with pine needles to a depth of eight inches, some of which may have been deliberately deposited to serve as a floor covering. No evidence of a central fireplace was noted.

No artifacts were found, nor was there any indication of historic contact. A pine tree more than eight inches in diameter growing in the enclosure suggested a respectable antiquity. One might infer that the tree could have begun its growth only after the house had been abandoned.

#### CONCLUSIONS

In all, eighteen house sites were observed, but a number of others have been reported. The construction varies somewhat between two general types: (A) the vertical-pole tipi-like structure illustrated by house sites 1 and 2 in the Little Cayuse Mountains; and (B) the horizontal-log cribbed structure represented by house site 3 in the Little Cayuse Mountains and the house in the Big Horn Mountains. These types occur in association with each other. In both, the wood superstructures were not cut or fitted, but were made of logs picked up in the vicinity and used with little working. In the cribbed type especially the pieces were fitted together very cleverly, for the

irregularities of the material were taken advantage of most ingeniously. In both types rows of stone slabs were usually placed about the outside of the walls when available. Several of the superstructures, particularly at Pompey's Pillar Cuesta, had been so completely destroyed that the type could not be recognized.

The vertical-pole tipi-like structures are separated into two subtypes: (A1) the hemiconical, built against the side of a cliff, represented by the two examples from the Little Cayuse Mountain village and by one from Thirty Mile Mesa; and (A2) the completely conical, built in the open and not supported against a cliff wall, represented by one example from Thirty Mile Mesa and by one from Razor Creek. A number of others were reported but not observed. Mr. Oscar Lewis stated that he saw many years ago a village of twenty-two in the Blue Mountains some twenty miles south of Glendive, but that at present all save one have been used for firewood by the local ranchers. Two were reported from the mouth of Teepee Creek in the Clark's Fork region of Park County, Wyoming.<sup>3</sup> Houses of this type were usually supported by a standing tree, one that sloped at such an angle as to form conveniently a portion of the wall. The vertical-pole houses usually had interior fireplaces, a characteristic unusual in the Little Cayuse Mountain examples.

The cribbed structures are also divisible into two construction subtypes. The first (B1) is usually rectangular, with one wall formed by the side of a cliff. It is represented by house site 3 in the Little Cayuse Mountains, by one on Razor Creek, and, possibly, by a number on Pompey's Pillar Cuesta, with very badly destroyed superstructures, among which are several with two or more sides formed by cliff scarps. The second subtype (B2) has no cliff support, and all the walls are of logs; it is either rectangular or pentagonal. Frequently houses of this subtype are partly supported by a standing tree that forms a section of the wall at one corner. These are represented by the Big Horn Mountain site, by three at Thirty Mile Mesa, and by several more reported by Mr. Oscar Lewis from the Hoskins Basin just north of Billings.

The cribbed structures characteristically have a lateral door and a central fireplace, but at the Big Horn Mountain site both of

<sup>3</sup> Frost, Nedward M., "The Sheep Eaters?" *Wyoming Wildlife Magazine*, 6 (1941): 17-19.

these usual features are absent. The roof construction is problematical, for in no case did the cribwork remain to a height of more than five feet. Originally the logs may have been cribbed all the way to the top, and thus have given the house a vaguely beehive appearance, or horizontal logs could have been laid across the cribbed walls with equal effectiveness.

Very few artifacts were found in association with the structures. A small number of gunflints and trade beads turned up at Thirty Mile Mesa, together with several planoconvex end scrapers, some side-notched concave-base projectile points, and other unstylized artifacts of chipped stone. Similar material occurred at Pompey's Pillar Cuesta, although no historic objects were noted. The other sites were almost entirely without artifacts. A few fragments of pottery were discovered near the house sites at both Thirty Mile Mesa and Pompey's Pillar Cuesta. They are gray to buff, with coarse paste-and-sand temper. In some the exterior is fluted, as though it might have been beaten with a thong-wrapped paddle. Pottery of this type occurs in small quantities on the surface in many places throughout this part of the Yellowstone Valley. It is similar to that of Pictograph Cave IV, an early historic occupation of Pictograph Cave, near Billings.<sup>4</sup> Some of the chipped-stone artifacts also might be considered vaguely similar to those of this complex.

As a rule, the locations chosen were on and about rugged sandstone escarpments in wooded areas, apparently because they afforded concealment and the opportunity to observe a large expanse of surrounding territory. Sites were evidently not selected with a view to repelling an attack, for most of them were indefensible. Villages were not usually closely centralized; the houses were often at some distance from one another. Completely isolated houses were frequent. The paucity of artifacts and camp débris suggests that the villages were not intensively occupied over long periods of time, but, rather, that they may have been used intermittently by small groups as temporary camps.

The actual tribal designation of the people who built these houses is obscure. Probably they cannot be assigned to representatives of any one tribe. The Crow, in whose historic area the villages

<sup>4</sup> Mulloy, William, "Ancient Caves of the Yellowstone Valley," unpublished manuscript in the files of the Montana Archaeological Survey.

lie, were accustomed to make log lodges of the conical type (A2), which they used primarily in war, but also as supplementary shelters to their usual tipis and for other temporary needs. They also believed that other tribes in the surrounding areas made similar lodges and specifically attributed the horizontal log structure to the Piegan. They believed, however, that most of the neighboring peoples, as well as they, knew how to make all the types and might construct any one of them upon occasion.<sup>5</sup>

UNIVERSITY OF MICHIGAN

<sup>5</sup> The remarks about the Crow are based upon information gathered by Mr. Fred Voget in the course of his ethnological investigations among that group.



# HOPI NOTES FROM CHIMOPOVY

WILSON D. WALLIS

*University of Minnesota*

AND

MISCHA TITIEV

*University of Michigan*

## PREFACE

THE information contained in this article was obtained from Joshua He'-mī-yesī-va (Humiyesva), a native of the pueblo of Chimopovy on Second Mesa, Arizona, during the course of a three weeks' visit to Philadelphia in May, 1912. The informant, who was then about forty-two years of age, was a student at the Carlisle Indian School. Arrangements for his visit were made with funds supplied by the University of Pennsylvania Museum, to which grateful acknowledgment is made.

The material was secured by Wilson D. Wallis, and is published by permission of the director of the University of Pennsylvania Museum. A few notes were also made by Wallis, and some have been added by the late Dr. Elsie Clews Parsons; but most of the comments and comparative data have been contributed by Mischa Titiev.

So little material has been reported from Chimopovy that the writers have decided to publish the following notes in full, in order to provide as good a basis as possible for comparison with information dealing with other Hopi towns.

## FOODS

### *Baked Sweet Corn*

Baked sweet corn is prepared in this way:<sup>1</sup> When the husks are slightly yellow, the ears are put on coals in a *koisa* (*gōsi*), a big hole in the ground, which is then covered with a large stone, sealed around the edges with old blades and husks and heaped with earth to keep in

<sup>1</sup> For Third Mesa practice see M. Titiev, "The Hopi Method of Baking Sweet Corn," *Pap. Mich. Acad. Sci., Arts, and Letters*, 23 (1937): 87-94. 1938.



the steam. The corn is left thus overnight, and before sunrise on the following morning an aperture is made to allow some of the steam to escape. About an hour later the earth is removed, and the stone cap is taken off. Because of the hot vapor this is a difficult task. Corn so prepared is good medicine, and it is believed that weak or affected parts of a person's body are benefited if he stands in the hole while throwing out the hot ears of maize. Later in the morning people arrive to pull off the husks and to eat the steamed corn, which is free to all who come.<sup>2</sup> This food is said to be very nourishing and stimulating.

#### *Kwivtosi*

A favorite drink made with white shelled corn as a base is known as *kwivtosi*.<sup>3</sup> The kernels are boiled in a pot of water, strained, and dried in the sun until they become hard and crisp. They are then placed in another pot, along with a handful of clean sand, and the mixture is heated and stirred until the corn cracks. Afterward the sand is sifted out, and salt is added. According to the informant, this is believed to have been the method of preparing corn before the Hopi learned to use grinding stones.

#### *Cactus*

The *yonga* ("cactus") is a plant which yields berries that are good to eat.<sup>4</sup> They are very sweet and grow in a long pod. The Hopi pound and shape them into cakes, which they keep all winter. They stir in hot water until the mixture is soft and then drink the concoction.

#### *Coyote*

The coyote has a disagreeable odor and is now seldom eaten,<sup>5</sup> but a long time ago coyote flesh was prepared as food in this way: The

<sup>2</sup> Compare Titiev, *op. cit.*, pp. 90, 91, and note 3.

<sup>3</sup> On Third Mesa a food known as *tosi* is made of finely ground sweet-corn meal, which is often dissolved in water and drunk. According to E. Beaglehole, *Notes on Hopi Economic Life*, Yale University Publications in Anthropology, 15 (1937): 67, note 8, *kwivtosi* is made by a bride.

<sup>4</sup> *Yonga* is probably the plant identified as *Opuntia polyacantha* Haw. by A. F. Whiting, *Ethnobotany of the Hopi*, Bull. 15, Museum of Northern Arizona, 1939, p. 85. He cites Hough to the effect that the edible fruits are picked with wooden tweezers and rolled in sand until the spines are removed.

<sup>5</sup> Wallis' informant likewise stated that "A long time ago it was the custom to eat the flesh of dogs." In *Hopi Journal of Alexander M. Stephen* (edited by

meat was first washed well in water into which cedar needles had been placed, soaked in a similar mixture, and again washed. When it was entirely cleaned, little odor was left. The meat was placed in a hole in the ground, and a very hot fire was made, over which was set a cooking pot containing water and cedar needles. Into this were thrown the legs and large pieces of the coyote's body. A cover was put on the pot, and the meat was allowed to cook for an entire day. The flesh was said to be good but to have a strong flavor.<sup>6</sup>

### Famine

When no one raised corn, and the people had nothing to eat, they tried every weed that grows, to see if it was fit to eat. They found some to be strong and sour. The Hopi moved east into the pueblos of New Mexico now occupied by them,<sup>7</sup> because in this region there were better things to eat. The following tale describes such a migration.<sup>8</sup>

The year that my father married, all the corn died when it was only a few inches high, killed by sun and drought. There were no watermelons, no peaches, no beans. Many of the Hopi went into New Mexico to spend the following winter. Until the next spring my [maternal] grandmother, grandfather, mother's sister, and mother's brother lived in Zufi. One day when a man started from there for a Hopi pueblo, my grandmother said to him: "Tell my son-in-law to come get corn and plant it." The man delivered his message: "Go to your mother to get corn for planting." My father went, and took with him some body paint and some women's clothes. The paint protected his face from the burning rays of the sun. He found my grandmother and my grandfather. In Zufi there was abundant food. My grandmother said to him, "Go with my husband to Acoma. There they have plenty of corn and will sell cheaply." My father gave her a burro, in order that she might go along; but the following day my grandmother said, "I shall not go down, let someone else go." She was working for a Zufi man, weaving blankets. At Acoma my father bought a big sack of corn with these blankets, and returned to Zufi. My grandmother made some *piki* for him. He then had plenty of food. My father came home alone,

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Elsie Clews Parsons), p. 266 (Vol. 23 [1936] in *Columbia Contributions to Anthropology*) there is a description of dog eating that took place on February 15, 1893. This work will hereafter be cited as *Hopi Journal*.

<sup>6</sup> Hopi informants at Oraibi stated in 1933-34 that coyote meat was inedible, but E. C. Parsons, *Pueblo Indian Religion* (1939), p. 22, notes that it was eaten in times of scarcity.

<sup>7</sup> "Apparently a reference to the belief as held on First Mesa that the people of Laguna and Acoma migrated from Hopi land." (E. C. P.)

<sup>8</sup> Compare the famine-caused migration described by Stephen in *Hopi Journal*, p. 1022. The same source, pp. 1035-1036, gives an account of the Hopi use of wild potatoes under normal conditions. For additional comparative data see Beaglehole, *op. cit.*, pp. 69-71.

the others remaining at Zufi. It was in the early spring. There had been a great deal of rain and snow that winter, and the fields had been well watered. The sweet corn was planted first, then the late corn. In July the sweet corn was well ripened. Some of the people ate too much of it, became sick, and died. Others were more moderate, ate sparingly at first, then a little more, and so on, to avoid getting sick. Some of the people were nearly famished, and were mere skeletons. In July and August watermelons, squashes, and pumpkins were plentiful. My father then sent a man to Zufi to tell his father and mother<sup>9</sup> to come to the Hopi pueblo, for they now had a large supply of corn and other foods. The messenger said to the mother: "Your son-in-law now has lots of things to eat. He wants you to come home." "All right," she said. They returned, and all lived together. None of them had died during this famine.

#### MATERIAL CULTURE

##### *Bedding*

Beds are made of rabbit-skin rugs (*tavapa*) and of sheepskins placed on the floor in four or five layers. The rugs are woven by women, who cut rabbit skins into strips, twist, and weave them. Clothes and old blankets are rolled up to serve as pillows. On one side of the room there is a pole, supported on uprights, from which the bedclothes hang during the day.

##### *Fire Drill*

Before matches were introduced the roots of the cottonwood tree were used as punk in kindling fire, and the fire drill was employed for creating a spark.<sup>10</sup> It was twirled between the palms of the hands, first slowly, then gradually more and more rapidly until smoke came, after which it was rotated as quickly as possible. As soon as a glow appeared, the operator removed the drill, put a piece of punk over the glowing wood, and blew on it until it flamed. He then held a piece of burning punk toward the Sun, who causes wood to burn. After that he put on other pieces of wood, as did the makers of war material.<sup>11</sup>

##### *Awls*

Awls are made from the sharp end of the *tamoala* pod, which is hardened by heating near a fire.

<sup>9</sup> In the Hopi kinship system terms for relatives-in-law are nonreciprocal. Thus the narrator's father refers to his mother-in-law as "mother," but she always calls him "son-in-law."

<sup>10</sup> The contemporary use of the fire drill in kindling new fire during the tribal initiation ceremonies is a striking example of religious conservatism in material culture.

<sup>11</sup> See p. 554.

Colored Soils<sup>12</sup>

A long while ago nearly all of the earth was burned in a conflagration that came within about ten miles of the Tusayan (Hopi) villages. Those parts that were severely burned are red, while those that were only partly scorched are black. In other places there are yellow rock and yellow soil, which turn red when subjected to fire. From these sources comes the red pigment used by the Hopi. The old people used to dig it up for making designs on pottery. When put on hides it made them smooth.

The Indians experiment with everything, some through careful thinking, and some through dreams that have a special meaning. Thus they find out about things and utilize their environment.

BIRDS<sup>13</sup>

*Angwusi*, crow, a bird that will steal all the time. Crows come in large flocks, tear up the corn and eat it, or fly to the fields before sunrise, to eat the water-melons. Children must be constantly on hand to frighten them off. Scare-crows, imitative of a man holding a bow and arrow in the attitude of one about to shoot, are sometimes used. Members of the Navaho or the Apache tribes are dubbed crows. It is believed that they assume the form of crows and, in that guise, go to ravish the fields of the Hopi.<sup>14</sup>

*Batsaiu* (713c), desert cactus wren (*Helodytes b. anthonyi*), which lives near pumpkin or squash vines. It is easily frightened. Prayer offerings made from the feathers of this bird are used when planting pumpkins.

*Balakwaiyu* (357), pigeon hawk (*Falco columbarius*).

*Bawaklaiya*\* (613), barn swallow (*Hirundo erythrogastra*), a fast flier.

*Blaso* (382.1), thick-billed parrot (*Rynchopsitta pachyrhyncha*). The tail feathers are worn as headdresses in many dances, and are much prized for their beautiful colors. The informant was very anxious to have one of these birds.

*Botro* (266), Eskimo curlew (*Numenius borealis*).

*Djaiwa* (480), Woodhouse jay (*Aphelocoma woodhouseii*). A bad bird which sometimes twists people about until they die. When flying, it twists and turns suddenly, often diving so quickly that no one can hit it.

*Heawi* (320), ground dove or mourning dove (*Columba gallinapasserina terrestris*).

<sup>12</sup> See Beaglehole, *op. cit.*, pp. 55-56.

<sup>13</sup> The identifications of native birds were made from colored figures in F. M. Chapman and C. A. Reed, *Color Key to North American Birds* (New York, 1903). The numbers in parentheses are those used in that volume. Compare the list of birds known to the Hopi in E. A. Mearns, "Ornithological Vocabulary of the Moki Indians," *Am. Anthropol.*, Old Series 9 (1896): 396-403.

<sup>14</sup> Compare E. C. Parsons, *Pueblo Indian Religion*, p. 578, note \*, where it is said that "Navaho are believed to transform into crows." This implies that the Navaho (and Apache) are witches, for the Hopi believe that sorcerers take animal forms whenever they do their evil work. See M. Titiev, "Notes on Hopi Witchcraft," *Pap. Mich. Acad. Sci., Arts, and Letters*, 28 (1942): 549-550. 1943.

*Honwika*\* (359), Aplomado falcon (*Falco fusco-caerulescens*).

*Hopanga* (412), southern flicker (*Colaptes auratus*). The native term for this bird comes from the word *pangawangaukina*, "to rap," as on a door; "to peck."

*Hosboa* (478b), long-crested jay (*Cyanocitta s. diademata*).

*Kela* (360a), desert sparrow hawk (*Falco s. phalaena*). The bird that first attempted to find a way out of the underworld for the Hopi.<sup>15</sup>

*Kisa* (360a), desert sparrow hawk (*Falco s. phalaena*).<sup>16</sup>

*Korani* (381), elf owl (*Micropallas whitneyi*). Believed to be the female of smaller owls.

*Kusongu*\* (310), wild turkey (*Meleagris gallopavo silvestris*).

*Kuku* (378), burrowing owl (*Speotyto cunicularia hypogaea*). The name of this bird is imitative of its call. It is said to be able to kindle a fire and then to add fuel to it.<sup>17</sup>

*Kwamakwa rinyaa* (408), Lewis woodpecker (*Asyndesmus torquatus*).

*Maiiyairo* (685), Wilson warbler (*Wilsonia pusilla*).

*Makilotaa* (440.1), white-eared hummingbird (*Basilinna leucotis*).

*Manani mowa* (376), snowy owl (*Nyctea nyctea*). Believed to be the female of the western horned owl (*takangmowa*).

*Mutcani* (621), northern shrike (*Lanius borealis*). The first creature to make its way out of the underworld.<sup>18</sup> It is a "very honest bird."

*Paladotsa* (426), Rivoli hummingbird (*Eugenes fulgens*).

*Sahemongwa* (373d), Kennicott screech owl (*Megascops a. kennicottii*); or else (366) American long-eared owl (*Asio wilsonianus*).

*Sakwadotsa* (427), blue-throated hummingbird (*Coeligena clemenciae*).

*Sikladotsa* (433), rufous hummingbird (*Selasphorus rufus*).

*Siklatci* (637), prothonotary warbler (*Protonotaria citrea*).

*Sikomi* (552), lark sparrow (*Chondestes grammacus*).

*Solcava nafnatoka* (506), orchard oriole (*Icterus spurius*). It comes in the autumn, and is said to feed partly on human excrement. For this reason the Hopi call the female *kvilasona* ("feces seeker").

*Takangmowa* (375a), western horned owl (*Bubo v. pallascens*).

*Tapaskwa* (710), California thrasher (*Toxostoma redivivum*). A bad bird, used by people to work evil magic.<sup>19</sup> While you are lying down asleep during the day, this bird may come and twist your heart. He may twist it so violently

<sup>15</sup> In Hopi myth all mankind originally lived in an underworld, from which they ultimately emerged to the earth. See H. R. Voth, *The Traditions of the Hopi*, Anthropological Series, Field Columbian Museum, 8 (1905): 10-11. In this version it is a bird called Mutsni (Mutcani), rather than Kela, that first tried to find an exit for the Hopi.

<sup>16</sup> Kisa is not always identified with Kela, as it is in this list. In *Hopi Journal*, p. 100, *kishsha* (kisa) is given as Cooper's hawk or sparrow hawk.

<sup>17</sup> "I have found a similar notion in connection with the owl among the Micmac of New Brunswick and Nova Scotia, who believe that anyone who imitates the call of *guguwelc* will be visited at night by this owl, which will burn the thing that he most treasures. The so-called Moors of Sussex County, Delaware, attribute to the turtle dove the design and ability to cause any imitator to be burned when he hears a fire." (W. D. W.)

<sup>18</sup> See note 15. Mochini (Mutcani), a small grayish bird, is said in *Hopi Journal*, p. 138, to have taught the songs used by the Agave and Lakon secret societies.

<sup>19</sup> See note 14, above.

as to rouse you from your sleep. When you get up and walk off, your sight grows dim and you go round and round, like a drunken man.

*Talcikwa* (unidentified). Also a bad bird. He, too, may twist your heart so that you will not be able to walk straight. With all his harmful ways, however, he is not so potent for evil as is *tapaskwa*, the confusing thrasher.

*Táctivol* (707a), Palmer thrasher (*Toxostoma curvirostre palmeri*).

*Tairo* (probably 474d), Texan horned lark (*O. a. giraudi*). All these birds, because of the "horns" on their heads, are believed to be males.

*Tcoro* (598), indigo bunting (*Cyanospiza cyanea*). The feathers of this bird are affixed to prayer sticks because, being from a winter bird, they ensure snow, which means that the ground will be well watered when it is time to sow the crops. The informant also identified *tcoro* as 599, lazuli bunting (*Cyanospiza amoena*), although he said that he had seen only one specimen of this variety.

*Tokulaka* (499?), bicolored blackbird (?) (*Agelaius gub. californicus*). Doubtfully identified as a variety of blackbird, inasmuch as a similar bird known to the informant has a yellow breast.

*Warinyawi* (413), red-shafted flicker (*Colaptes cafer collaris*). The female of this species is said to be 414, gilded flicker (*Colaptes chrysoides*).

*Wawaioma* (524), gray-crowned leucosticte (*Leucosticte tephrocotis*). A winter bird.

*Wisokwa* (325), turkey vulture (*Cathartes aura*).

*Yapa* (703a), western mocking bird (*Mimus polyglottis leucopterus*). This bird gave their languages to the Hopi and all other human beings.<sup>20</sup>

#### CHILDBIRTH AND NAMING CUSTOMS<sup>21</sup>

Someone learned, in a dream, the proper way to take care of babies. The grandmother washes the newborn infant, and rubs over it ashes mixed with red earth. These are allowed to remain on the child for twenty-five days, and are said to remove its entire skin. "This is why we have no hair on any part of our bodies, and why our skins are so smooth. One Hopi, when an infant, was not given this treatment and, as a result, he has a mustache and a beard that cover his entire face."

Just before parturition cedar needles are boiled in water for about an hour, together with grains of white corn. The solids are eaten by a woman in labor, and the broth is drunk. Some of the mixture is also put on her stomach and into the vulva, in the belief that it eases

<sup>20</sup> Compare Voth, *op. cit.* (see note 15), p. 11. According to *Hopi Journal*, p. 138, Yapa also taught songs to the Singers, Wuwutcim, Flute, Marau, and Oaqól societies.

<sup>21</sup> Comparative material from other Hopi villages may be found in E. and P. Beaglehole, *Hopi of the Second Mesa*, Mem. Am. Anthropol. Assn., No. 44 (1935): 30-38; J. G. Owens, "Natal Ceremonies of the Hopi Indians," *Journ. Am. Ethnol. and Archaeol.*, 2, No. 2 (1892); and E. C. Parsons, "Hopi Mothers and Children," *Man*, 21 (1921): 98-102.

delivery. It is used as a palliative for the pains of childbirth, and is placed in the nostrils and ears of the mother in order that the smell of blood may not sicken her. If she becomes faint, this medicine revives her at once.<sup>22</sup> It also facilitates the expulsion of the afterbirth.

On the twenty-fourth day several women cook all day, using a big pot in which they boil meat and corn. Next morning the baby's grandmothers and its father's sisters come to wash the hair of the mother and to give names to the child. Each of the father's clanswomen may bestow a name on the child,<sup>23</sup> and one of the suggested designations ultimately "sticks." Throughout the first twenty-five days after childbirth the mother eats neither meat nor salt, and may not leave the house.

The informant gave the following account of the appellations he had received. His grandmother was dead when he was born; his father's sister took her place, and named him on the twenty-fifth day. He was given another name by a person whom he did not know. At the time of his Katsina initiation his ceremonial father gave him a new name; and from then on he called this man "father" and treated his ceremonial father's relatives as if they were his own.<sup>24</sup> The same individual and his sister's daughter gave him his manhood names when he went through the tribal initiation (*Wuwutcim*) ceremony. After this he no longer played with his former mates, for he was no more a boy, but remained a dignified nonparticipant in their game and frolics.

A long time ago neither the Americans nor the Hopi practiced baptism (Catholic baptism). The Americans said to the Hopi: "It is not good for you, do not use it"; but the Mexicans told them: "If you baptize, you will have good luck and go to heaven." The Americans retorted, "Do not baptize. If you do, you will soon die and go to live down in the earth, like the Mexicans and the Spaniards."<sup>25</sup>

That baptism is a bad thing for the Hopi is proved by this in-

<sup>22</sup> Titiev, M., *Old Oraibi: A Study of the Hopi Indians of Third Mesa*, Pap. Peabody Mus. Am. Archaeol. and Ethnol., Harvard University, 22, No. 1 (1944): 186, reports that cedar has the power to kill Masau'u, the god of death. It therefore protects people in times of great danger. This work will hereafter be cited as *Old Oraibi*. <sup>23</sup> See E. C. Parsons, *Pueblo Indian Religion*, p. 80, note 1.

<sup>24</sup> For further information on this point see Titiev, *op. cit.*, pp. 12-13.

<sup>25</sup> This argument over Catholic baptism is a modern example of an ancient debate that goes back to the time of the Spanish Conquest. See Titiev, *Old Oraibi*, pp. 70-71.

stance: "My uncle, who died about six years ago, was a bad man [witch]. He would turn over and become a coyote or a crow. He was baptized in New Mexico, as was also my half-brother. My uncle died two or three months after he came home, for he was a very bad man.<sup>26</sup> 'When I die,' he said, 'I shall become a Mexican. Do not look for me.'<sup>27</sup> If someone asks you to baptize, do not do it; do not touch it [i.e. have nothing to do with it], my nephew, for it does not belong to you.'<sup>28</sup>

MARRIAGE AND DIVORCE<sup>29</sup>

If a boy and girl like each other and wish to be married, the boy seeks his mother's approval of the match and the girl asks her father if he will consent. The parents take a while to think about it. Perhaps they will approve, perhaps disapprove. If both parents agree, they will be married. However, the girl's father may say to her: "He is not a good boy, I do not want him as a son-in-law. The next time he comes to see you, he may give the lie to his previous promises and say that he does not want to marry you. He may like some other girl and be merely fooling with you. Ask him questions." It may be that the boy does not like anyone else, and goes back to see this girl. She tells him that her father disapproves of the match, and asks him questions designed to test his devotion to her. After this, if all goes well, he comes from time to time to see her.<sup>30</sup>

Formerly marriages were held only in January and September. In the latter month there was always abundant food. All the men and women go to a nuptial feast, for there is plenty of *piki*, which has been baked at the home of the groom. When preparing for a

<sup>26</sup> The punishment for witches is death. Consult M. Titiev, "Notes on Hopi Witchcraft," *Pap. Mich. Acad. Sci., Arts, and Letters*, 28 (1942): 554-555. 1943.

<sup>27</sup> The Hopi believe that the souls of ordinary people can be recognized in the other world, where life is a shadowy replica of earthly existence. The spirits of witches, however, are turned into beetles. See Titiev, *op. cit.*, p. 556. Hence an acknowledged sorcerer knows that his relatives will be unable to find him in the afterlife.

<sup>28</sup> Hopi uncles are expected to instruct their nephews in all aspects of tribal lore.

<sup>29</sup> A comprehensive study of Hopi courtship, marriage, and divorce may be found in Titiev, *Old Oraibi*, pp. 30-43.

<sup>30</sup> On the basis of recent evidence I strongly suspect that the phrase "comes to see her," is a euphemism for "comes to sleep with her." (M. T.)



marriage, the women in the boy's household are busy all the time grinding cornmeal. Four or five days later the girl goes to the home of the boy. He brings in wood, and she works continually, grinding corn incessantly for three days.

On the fourth day the boy's mother takes down the girl's hair, which up to this time has been worn in two whorls, one on each side of the head, makes suds from soapweed, and washes her hair. The girl's mother then washes the boy's head. After this the mother of the groom says to the bride, "You are *imu'wi* (my daughter-in-law)." The girl now wears her hair in two strands, in the manner of married women.

The waters in which the hair of the bride and that of the groom have been washed are mixed together. Each of the mothers takes one half, puts a white rock (limestone?) into it, and stirs up suds. The water is sprinkled over the entire floors of both houses, to ensure that the couple just married will never separate and that each will remain attached to the other's home.

Sometimes another method is used. The boy and girl are seated beside each other, and one foot of each is placed in the same pot. They then bow their heads, which are washed in the manner described above, but in the same bowl of soapweed water. Strands of hair, taken from each of the principals, are twisted into one braid. This signifies that the bridal pair will always like each other, and will get along well. The informant had never seen this procedure, but he had heard about it and believed that it had been used by the people of a previous generation.

After the marriage ceremony the couple take up their abode in the boy's house. The men of the village come and weave there<sup>21</sup> until they have made two blankets. When these have been finished the groom procures reeds and binds them together with fibers to make a container for the wedding robes. He also prepares big moccasins out of deerskin, cutting them from the middle of the hide; and fashions long thongs, to be wrapped close together around the legs and worn as leggings.

<sup>21</sup> "This statement should be verified. On First Mesa they weave in kivas." (E. C. P.) It is likely that the informant is in error on this point, for wedding clothes are generally woven in kivas. For Second Mesa practice in the preparation of nuptial garments, and for a good chronological account of a wedding ceremony see E. Nequatewa, "Hopi Courtship and Marriage," *Museum Notes, Museum of Northern Arizona*, 5, No. 8 (1933): 43-54.

On the morning after the garments are ready the wedded pair go to the wife's house. She remains here for ten or twelve days, meanwhile keeping apart from her husband. At the end of this period she fills about a dozen baskets with cornmeal and proceeds to the home of the groom, where she stays until dark. The boy's uncle or his father then speaks to him and tells him how he will be expected to treat his wife: "You are now going to leave us; you will stay with us no longer; take care of her; do not go gadding about; do not be lazy; do your work as best you can; do not become angry with your wife. Live with her always and work for her, too."

About nine o'clock they say: "You had better go home now." The boy takes the large blankets with him, and they go to the bride's house. Her father or her uncle says: "Come in!" They talk to her and tell her things of the same purport as those told to the groom. "Now, my daughter, you are married. Do not oppose your husband. Merely remain at home all the time and cook for him. Do not go away anywhere."

The bride, if she heeds her father's words, stays home, does not get angry with her spouse, and talks always in a mild tone. Possibly, however, the girl is of no account, and likes some other man. She is then always asking her husband to go away and get things for her. She is away a great deal, seldom at home. When the man returns from his work in the fields, he finds no one in the house. After a while she comes back, and says: "Oh, I went out merely for a moment a little while ago." She chooses someone else for a mate. In this way she finally forces him to say something disagreeable to her, to quarrel with her because of her incessant gadding about. When this happens, she gives him his possessions, perhaps his blanket and saddle, and says: "Now you may go back to your own home."<sup>32</sup>

He leaves. On the following day his wife may go to his house, cook for him all day, and at night she may say: "Now, let us go to our room." "No," he may reply, "I do not wish to go." In that case, after supper he leaves and goes to some other house; perhaps he visits some of his friends. She may wait and wait for him, but he

<sup>32</sup> Among the Hopi, postmarital residence is always matrilocal, which means that a groom leaves his own mother's home and goes to live in his wife's or wife's mother's house. In the event of a separation, therefore, he has no choice, but must leave his wife's residence and return to his own mother's household.

will not return. She remains there. The man gets angry and says to his mother: "Why do you not send her back to her home? I do not want to be with her." Finally she is sent back to her own dwelling.

Perhaps, after another half year, the woman will return and try to induce him to take her back. But he will not do it. She may then follow him off somewhere in an attempt to win him back. But he will say: "Do not follow me any more — you will only make trouble for me. I do not want you." Perhaps she will never cease trying to get him back.

On the other hand, it may happen that the man will see another woman and marry her. If he does so, his first wife will bother him no longer,<sup>33</sup> but may be angry with the second wife and, perhaps, fight her. Sometimes the wife is good and the husband is of no account. A husband may like another woman and abandon his own spouse in order to get the other woman. It appears, however, that a man will not have more than one wife at the same time, possibly because he cannot live in two homes at once.

*Imadiwa* is a term used to refer to one's sweetheart. It is customary to marry the daughter of one's father's sister, who is always of a different clan.<sup>34</sup>

#### SNEEZING

Sneezing (*eskan*) means that your friend is thinking or talking about you. The Hopi say to one who sneezes, "Perhaps your father's sister (*ikya'a*) wants you," meaning that there may be a girl [her daughter?] who wants to marry you. Or, sometimes, the one who sneezes says: "Maybe my girl is talking about me."

#### DREAMS<sup>35</sup>

Dreams (*tamukvala*) are sometimes of good omen, sometimes evil, presaging death. After a bad dream you will feel dejected. You

<sup>33</sup> Permanent separation of spouses amounts to a divorce in Hopi society, and remarriages are generally arranged without ceremony.

<sup>34</sup> "There are hints, but only hints, of cross-cousin marriage at First Mesa." (E. C. P.) The possibility that Hopi men once were expected to marry their fathers' sisters' daughters has been studied by M. Titiev, "The Problem of Cross-Cousin Marriage among the Hopi," *Am. Anthropol.*, 40 (1938): 105-111.

<sup>35</sup> Additional material on this topic occurs in E. C. Parsons, *Pueblo Indian Religion*, pp. 87-88, *et passim*; and in E. and F. Beaglehole, *op. cit.* (see note 21), pp. 15-16.

may dream that someone is sick, or that some misfortune has befallen one of your relatives; possibly he has fallen down and hurt himself.

If you dream of any kind of katchina, it will rain hard and long. Should you dream of a large body of running water, such as a creek flowing in muddy torrents, turbulent and full of sand and earth, the following morning may be nice, but by seven or eight o'clock a big wind will rise and fill the air with dust and sand. Such a dream is not a good one.

You may wish to go hunting and be thinking about rabbits, deer, and other game. Soon you will have a dream. You will dream of a girl, for all the rabbits are female — or nearly all of them — and they are spoken of in this gender. For this reason rabbits are fond of girls, and girls wield an influence over them. Should you dream of a boy, you will kill perhaps one rabbit. Should you dream of a girl, you will kill more than one. Should you dream of a boy and a girl, both of them appearing close to you and neither saying a thing, you will miss the rabbits that you hunt on the next day — you will not hit any of them; or you will kill only one and miss all the others. As with rabbits, so with other animals.

Good dreams in December mean a bad season the following summer; bad dreams in December mean good weather during the next summer. For example, should you dream of little wet spots all around you, you may look forward to a good summer; after December, however, such a dream is of no account at all, for no rain will follow as a result of it.

#### WITCHCRAFT <sup>26</sup>

When an infant is about thirty days old, someone may steal it away from its mother during the night, and give it to a spirit (witch?). When the child grows up it will be very clever and may know how to cause some kind of disease. If a youngster is taught this belief when five or six years old, it will certainly die soon. Someone may turn it into a coyote or a crow. If you look closely at the face of a person who changes himself into an animal, you can see beneath the surface of the skin the features of the beast which he becomes when transformed.

<sup>26</sup> Compare the treatment of this topic by M. Titiev, "Notes on Hopi Witchcraft," *Pap. Mich. Acad. Sci., Arts, and Letters*, 28 (1942): 549-557. 1943. See also E. C. Parsons, "Witchcraft among the Pueblos: Indian or Spanish?" *Man*, 27 (1927): 106-112, 125-128.

When crows go into our fields and peck our watermelons full of holes, we know they are Navahos or Apaches who have come in this guise.<sup>27</sup> Sometimes there will be two or three exceedingly bad crows which will keep pecking at corn or melons until they have consumed nearly all of them. When this happens, you may be sure that the birds are Apaches or Navahos. Sometimes we hide and kill such a crow. Soon after this a man in one of these tribes will die, whereupon one of their medicine men will say: "Someone has shot that crow."

My brother's wife was once sick. Their dog barked all night. "Something is wrong," they thought. About sundown the next day my brother went up on the housetop and lay down, with revolver concealed. He thought that something might come to the house. In a little while the dog began barking. It barked again. Soon he saw a cat coming along the edge of the flat roof. The cat climbed up, looked about cautiously, then went over close to my brother. It became frightened, turned around, ran away, and jumped off from the other side of the roof. My brother kept watch on the following night. Again the dog barked. Again the cat came, this time moving even more cautiously. When it saw my brother, it scampered away.

The next night my brother took his place, as before, to keep watch. This time a large dog came toward the house. Never had he seen a dog of that kind in any part of the village. It was a large yellow beast. The wife of my brother, who is a silversmith and has a small house, was now very sick, and lay groaning. Now that dog came along. "Ahem!" thought my brother. "I guess this is something else. Never have I seen a dog of that kind." He prepared to shoot. The dog started up, but instead of running straight [as a real animal would do], it ran a zigzag course. My brother sent one bullet, then another, at him. He did not tell anyone about this, for in that case someone would be sure to say, "You have killed my dog," and he would have to recompense the owner.<sup>28</sup> After this, however, he kept his ears open for news. His wife improved a bit. A little while after this my mother's sister's daughter became sick. She was sick four days, with a very sore side and pains in the middle of the back

<sup>27</sup> Compare p. 527 and note 14, above.

<sup>28</sup> It is true that the slayer of a household pet is expected to pay damages, but the main reason why the narrator's brother kept secret the shooting of the doglike witch was fear of revenge. See Titiev, *op. cit.*, p. 554.

[near the kidneys]. A hole was noticeable on one side of her body. Over this place she had put some raw cotton. My sister saw this hole with the cotton in it. The woman stank terribly during this time, for fetid matter was oozing from the wound. She was sick a few days, then died. "I guess I shot her," my brother said. "I had never before seen a dog like that."<sup>39</sup>

My grandfather told me the difference between a good and a bad man, illustrating his words by the use of two fingers. The bad man goes a very crooked road, first ahead, then back; the good man travels straight ahead. When the bad man regains consciousness after a swoon, dream, or other unconscious state, he goes back [morally], because he has been all this while thinking of a way in which he can kill some man, woman, or little child. These bad people who can change their forms are marked on the forehead. Such a man can turn over through a hoop, become a coyote, for example, go somewhere at night, return in the morning, go back through the hoop, and become a man again, without anyone knowing anything about it.<sup>40</sup> People have often been detected in the act of transforming themselves, and their animal markings may be noticed under the skin.

A long time ago nearly everyone had one of the hoops that are used in changing to an animal and back into human shape. Such a hoop is decorated with the feathers of an owl, crow, whippoorwill, and eagle, all birds of strong medicine. A man who is transformed will perhaps go to steal something and will then bring it home. Sometimes all the Indians who do such things, and white people, too, meet at night. Their transforming hoops must be made of hickory, for a strong wood is required. To them are tied pieces of animals (in addition to the feathers already mentioned), by means of the hairs of wolves or of other creatures, or by leather thongs. If a man wishes to become a coyote, he places part of a coyote on top of the hoop; if a crow, he puts crow feathers on top, and so on. He places his head against the fragment of that animal whose likeness he wishes to assume, and prays: "Cause me to become a coyote!" Then he somersaults through the hoop.

I deliberated about these matters and eventually decided that my grandfather had told the truth. My grandfather said: "I tried it.

<sup>39</sup> For similar beliefs in other pueblos see Parsons, *op. cit.*, pp. 111-112.

<sup>40</sup> Compare Titiev, *op. cit.*, p. 550.

I killed my sister's little boy in that way. I took out his heart because it was young, and gave him mine.<sup>4</sup> He died. I gave him my life and I took his. Soon after this I got the life of another one by taking out his heart. He used my life, and I used his. He also died. But that is not good. Do not do it. Do not attempt it. I do not lie to you."

Not many years ago my mother's brother also tried this. The children of my younger brother and of my mother's sisters died, one after the other, when only one, two, or three years old; just as my uncle had taken my brother's life when he was two or three years of age. An older brother of mine, as he himself told me, got the lives of our sister's children. After a while a good medicine man found out about it and told us: "It is your brother who is eating the lives of these children; he is a bad man. Tell him so. He will then stop it, and you will have your children."

About ten years ago this brother died. He was very bad. He would not stay at home. He stole horses to sell to the Mexicans and to the white people. Other horses as well as cattle he killed with a revolver and ate. After a while that same good medicine man found out and told us. Soon my brother stopped these doings. He can no longer move about. He no longer steals the hearts of my nephews.

My uncle, who had stolen the life of my younger brother and put his own life into him, is now troubled; his mind dwells on this all the time; he covers his face with his blanket and sleeps continually. Then he says to me: "My nephew, let us go after the horses." (He has a great many horses.) We go, taking a boy with us. We send the boy ahead for the horses, while we rest by a spring. On one occasion he repeated the same thing my grandfather had told. He said: "I am a bad man; your father, however, is a good man, a strong man with a strong heart. He tells the truth, he never lies. That is why I cannot live tomorrow and the next day. Perhaps I shall die tomorrow, perhaps on the following day. For this reason, I am going away." (It was windy, windy, windy, and the clouds were gathering as if for a shower.)

"That is the kind of man I am," he continued, "nothing else. You may tell others about me — tell some other bad man. I am

<sup>4</sup> Compare Titiev, *loc. cit.*: "To prolong his own existence, each sorcerer is obliged to cause the death of one of his relatives annually."

going down into the earth. When you die, do not look for me in that world where good people go.<sup>42</sup> I am a bad man. I turn over into a coyote or a crow, go somewhere to steal something, and when I get back I turn over into a man again, and no one knows what I have done." This talk made me sad, for he was my uncle.

"Go away from here," I said to him. "You killed my sisters and brothers. I would have many more relatives now if you had not taken their lives. We care nothing about you. Go away. You would destroy all of us." I was angry with him. In a little while he began to cry. "What you say is true," he said. "Your heart is good. I know all about it. When I am dead my soul will not live anywhere, for I shall be merely cold ashes. When you die, you will live again. Do not do things of this kind," my uncle continued. "Maybe someone will attempt to teach them to you, but do not try them. If you refrain, you will have all your life. This is the last time I shall see you. Probably I shall never see you again."

This man was my mother's brother. After this he went into New Mexico, stayed there a year, and then came back. Siklalesiva [Sikyaletsiwa], the chief at Chimopovy [in 1912], is a friend of this uncle.

There is no punishment for such offenses. This is why these evildoers are not afraid to practice their arts, and why they are so plentiful. A man who has once begun to work evil magic cannot leave off, but keeps on. This is the reason we are continually having so much trouble.

A long time ago there was no sickness among the Hopi; there was no evil magic; it was not practiced. In this respect the old-time Hopi were like the white people. All that they ever suffered from was colds; no other sickness was known to them. Occasionally, one of these colds would be severe enough to cause death. It was not long, however, before certain people, more clever than the others, began to do evil magic, causing one form of sickness, and then another, and another. No one knew what medicine to take for these various ailments.

Once, when I was ten or twelve years of age, all the people were sick. They had coughs continuously, day and night, and were very ill. They were nauseated, and some swelled up in the abdomen and died. It was the first time we had ever had that sickness. Next

<sup>42</sup> See note 27.



year there was a new disease, the following year another, and so it went. Now there are several "doctors" in my village.

Certain young people, very clever, made these sicknesses. These are bad people. What I have told you is what my grandfather was always telling me. Sometimes he would talk to me the entire day as well as throughout the night, neither of us sleeping at all.

#### MASK-CAUSED SICKNESS

If anyone touches a katchina mask, the owner will be afflicted with sores over his whole face.<sup>43</sup> A mask, when not in use, is kept under the floor of a house.<sup>44</sup> The hole into which it is put is covered with a stone, and the opening is sealed with mud, so that no aperture is left. If part of the opening were not closed, some of the power of the mask would come out; and if this were smelled by someone, the owner would get a sore face. It is only in months during which the mask is not used in ceremonies that it will injure people.<sup>45</sup>

The katchina chief makes medicine to cure such an affliction. He burns cedar wood, gathers the ashes and puts them into a pot, and covers the embers with a blanket. He then throws the ashes into some place where they will not be seen; but whoever goes past the spot is likely to break out with sores. An afflicted man places his head over cedar embers, and is covered with a blanket. After this the sores will disappear.

If a person who tampers with another's mask should break out in sores, no medicine in the world can cure him. If he did not believe in the power of the mask, he could not be cured. Anyone who violates a mask will certainly be afflicted with a sickness in some part of his body. Furthermore, one who sees a mask at the wrong time, that is, when it is not being ceremonially used, will have sore eyes.

<sup>43</sup> The Hopi believe that all sacred objects contain the power to injure those who handle them. Accordingly, participants in rituals must always uncharm themselves at their conclusion. For the particular ailments associated with the major ceremonies on Third Mesa see Titiev, *Old Oraibi*, p. 241. I am not familiar with the concept that the owner is stricken ill if someone else violates his mask. (M. T.) Comparative data on masks may be found in E. C. Parsons, *Pueblo Indian Religion*, pp. 339-348; and in *Hopi Journal*, p. 371 and note 2.

<sup>44</sup> Ordinarily katchina masks are kept either in recesses within the kivas or in cupboards in their owners' homes. I know of no other report that mentions mask concealment under the floors of houses. (M. T.)

<sup>45</sup> This refers to the fact that Hopi katchina performances are celebrated from December to June and are forbidden during the rest of the year.

It is very bad to put on the Masau'u<sup>48</sup> mask except during ceremonies. To do so would bring sickness upon the desecrater. For example, even if a man were to steal a mask, put it on, and return it to its place without the knowledge of anyone else, nevertheless some misfortune would befall him on the following day. He might become blind, or his lips might close together so tightly that he could not open his mouth, even to tell the truth. On proper ritual occasions, however, the Masau'u mask can be used with complete safety. The young [uninitiated] people think the mask is only a piece of skin which will not injure anyone, for they do not believe what the owner says about it; but older persons are afraid of these masks and will not, under any conditions, touch them.

It sometimes happens that a little boy digs one out of the ground where it has been hidden, puts it on, and later replaces it. As surely as he does so, some misfortune will befall him; and his tongue may be "tied," so that he cannot pronounce his words correctly and he becomes a stutterer.

SPIDER<sup>47</sup>

Spider gives you long life. You may have done something wrong somewhere, or you may be injured, and you happen to step aside to micturate.<sup>48</sup> Then Spider will say: "My grandson, do not urinate on my house! Step just a little farther along!" Then you look and see Spider there. "Oh, my grandson," says she, "in case you have had bad luck or someone has harmed you, that is why I speak to you. Come into my house." "I cannot go in," you reply; "I am too large." "Twist your foot around in it," she directs, "and it will open." You insert your foot, twist it around, and Spider's house widens.<sup>49</sup>

Spider gives you an acorn cup and a piñon cup filled with water. You think: "This is not enough, it is only about a swallow." Then you start to drink and find that there is a great deal in the cup. She gives you a piece of *pavalpiki* [a food made from cornmeal]. You

<sup>48</sup> Masau'u is the god of death; hence his mask is exceptionally dangerous. See Titiev, *op. cit.*, pp. 236-238, *et passim*.

<sup>49</sup> "Spider" seems to refer here to Spider Woman, a popular figure in Hopi myths. She is the grandmother of the Little War Twins, patron of witches, and helper of and adviser to mankind. Her characteristics are discussed by E. C. Parsons, *Pueblo Indian Religion*, pp. 192-193, *et passim*.

<sup>50</sup> In many Hopi tales this is the customary way of meeting Spider Woman.

<sup>51</sup> Spider Woman's house is frequently so small that it must be widened before visitors can enter. Compare Voth, *op. cit.* (see note 15), pp. 162-163.

are about to put the whole piece in your mouth. "Do not take the whole piece," she cries. Accordingly, you bite off a tiny particle and chew it. Soon you have a big mouthful. Thus it is every time you take a small bit and chew it. You never finish eating all of it.<sup>50</sup>

That is why we pray to her. Suppose you have gone somewhere far from home. When you are ready to return, tell Spider. She always watches you, she listens all the time. If you believe in her, she will always assist you; if you do not believe in her, she cannot help you. A believer who is tired and hungry may say: "Grandmother Spider! Now, Grandmother Spider, help me! Help me to make the distance short!" Spider catches hold of the earth, pulls closer together the place where you now are and that to which you wish to go, and thus shortens the distance between them, so that you reach home quickly. This is what the story says, and this is the way people used to do a long while ago.

The white hairy spider is called *silkamaido*; the large brown hairless one, *basavtanga* (*basavi*, "cotton"). When you plant cotton, you should tell Spider: "I wish this cotton to grow." You may rarely see her, but, nevertheless, she hears you. Sometimes, after a rain, you may see her.

*Basavtanga* was the first to help the white people. She is the one who taught them how to write. *Silkamaido* also helped them. The white people kept *silkamaido* in a glass, and asked her where there was a good place to go. She pointed her finger, and in that direction they went.<sup>51</sup> That is why the railroad was run to Winslow and through Arizona. She knows everything.

Her grandson, Pukonghöya, made the rocks. When he first came up, the large tears from his eyes made the gullies and canyons. Spider gave him medicine, and told him to put it into his mouth and blow it out over the world. He did so. Palungahöya, the younger brother who makes the echo, went first into the creeks, and Pukonghöya followed him. So were running water and rocks made.<sup>52</sup>

<sup>50</sup> According to Parsons, *op. cit.*, p. 94, this is an example of "the so-called motif of the inexhaustible, found throughout America."

<sup>51</sup> "This recalls the pointing of 'granddaddy longlegs' among us." (W. D. W.) Dr. Parsons has also called attention to the way the site of Zuni was found by Waterskate, in "The Origin Myth of Zuni," *Journ. Am. Folk-Lore*, 36 (1923): 155.

<sup>52</sup> The elder of the Little War Twins is Pukonghöya, and Palungahöya is the younger. A variant account of their formation of the landscape occurs in A. M. Stephen, "Hopi Tales," *Journ. Am. Folk-Lore*, 42 (1929): 50-51. These tales were edited by Dr. Parsons.

## WEATHER PHENOMENA

*Drought.* — The informant felt bad when he saw the Hopi masks in the University of Pennsylvania Museum, for it meant that some evil people had stolen them and sold them to the whites. This treatment of masks invariably causes sickness, storms, winds, or some other misfortune. When, for example, old-time pottery was dug up about 1885, there was wind, wind, wind continually, but no rain; and the Hopi could raise no corn. During four successive seasons there was failure of the corn crop.

My father then said to those who had been digging up the old pots: "Stop! Stop! Do not take out any more!" I lent my assistance to his efforts. Soon a great many people began to heed our words. My father knew about the olden times, and in a little while all the pueblos respected his warnings, and refrained from digging up the dead. The following year we had a good summer. There was rain, rain, rain. Everyone raised much corn, watermelons, and peaches. As a result of our interference, however, some of the people do not like my father, and some of them dislike me, and say [of me]: "He tells lies. He is a liar!"<sup>33</sup>

*Wind.* — The wind comes out of holes in the ground 120 miles beyond Winslow. Formerly a Hopi policeman, *kaletaka* (literally, "warrior"), went every spring to kill the wind.<sup>34</sup> A cyclone came out first and sent the other winds scurrying off in all directions. The *kaletaka* would shoot into the wind as it was going past him, using perhaps several arrows. The cyclone spirit that makes the winds is called Ta'doif'bayan'gya [*duviphaiyan*]. It lives in the earth. It whirls around, then goes up high and whirls around up there until the winds come up to it. Sometimes an arrow is twisted round and round by Ta'doif'bayan'gya before it succumbs to the attack. When all of his arrows have been used, the *kaletaka* hurls a throwing stick until the spirit gradually ceases its gyrations and finally dies. My father had told me to be careful lest Ta'doif'bayan'gya kill me, for it is very bad. He said: "A big cyclone may come by and twist your whole body, or take out your eyes and brain!"

<sup>33</sup> "Here and elsewhere the stress on lying is very much like the emphasis throughout Mexico, where *es mentira* is constantly said of misrepresentations, deliberate or otherwise." (E. C. P.)

<sup>34</sup> "Compare Laguna." (E. C. P.)

This spirit is said to be a female with foul-smelling vulva.<sup>65</sup> It always avoids meeting a shower.

*Rainbow.* — *Bi'bitca* ("mud daub") had its origin in the rainbow. If you go to the end of a rainbow, you will find a hard, tough ball of yellow material that looks like corn pollen. This is potent medicine. It is the excrement of the rainbow.<sup>66</sup> It may be eaten, and it also imparts wonderful power to a *paho* ("prayer stick"). The finder should put it under a bush and say nothing about it.

A rainbow seen in the west in the evening is a sign of rain the following morning; if it is seen in the east in the morning, rain may be expected that same afternoon.

If one deliberately points at the rainbow, a finger will soon be lost. It will become sore, turn white under the nail, and rot off.<sup>67</sup> Should one point at it thoughtlessly, these dire consequences may be averted by putting the finger in the mouth and biting the nail hard. After this precaution no harm will follow.

*Rain.* — If you wish rain, go with a pipe and tobacco to the headman of the Water clan. Sometimes he will offer you something to eat. You then take four puffs at your pipe, after which you eat of the food. When through, you say: "I have enough, thank you." He asks: "What is it that you wish? What can I do for you? Is something wrong?" "Yes," is the reply. "I have been thinking today. There is no rain, the ground is hard, the corn poor. I want some rain. Let us pray, perhaps it will rain." "I shall try," answers the Water clan chief; "perhaps it will rain. If you do not lie, we may procure rain." "I never lie," you say. "I wish some rain." "Then," replies the headman, "if your heart is good, and you are upright, we shall get rain," and he begins to pray.<sup>68</sup>

You wait four days for the rain to come, during which time you think about it continually. If it arrives it makes everything grow, but occasionally something goes amiss, and no rain falls.

This is the way the story says we must do all the time. Now,

<sup>65</sup> "Generally referred to as Wind Old Woman." (E. C. P.) See also Parsons, *op. cit.*, p. 178 and note †.

<sup>66</sup> Compare Beaglehole, *op. cit.* (see note 3), p. 25.

<sup>67</sup> Compare Beaglehole, *loc. cit.*

<sup>68</sup> According to Titiev, *Old Oraibi*, p. 106, there is a general Hopi belief "that only those who know their minds to be good (untroubled) are fit to have their prayers heard by the gods." The particular dialog given above supports the general statement and is an interesting expression of ethical and psychological attitudes.

however, the young people do not believe it. I do not know how they plead for rain. They think only about horses and horseback riding.

Never forget this story and you will always have food to eat and will encounter no hard times. Even though you grow rich in sheep and horses and have good clothes, if no rain falls, you will have no corn. Then, when you become hungry, these [superfluous] things are of no avail. Do not buy from others, raise for yourself all that you need in summer and sufficient to keep you during the winter. This, too, is what the old story says.

*Lightning and thunder.* — Those of the dead who were good people while on earth become Cloud People after death.<sup>59</sup> They have a round, nearly flat tray made of cotton, called *ba'taawola*, in which they carry water; another in which lightning is carried; and a third in which thunder is kept. Men, women, and children of either sex carry these. They lift them up to the wind, and water sprinkled from them causes rain. They [the Cloud People?] <sup>60</sup> take water out of these trays with their hands,<sup>61</sup> and sprinkle it out into the air, but never throw out all of it.

The lightning is kept in a pot. When the lid is opened, it darts out. When the cover is taken off another pot, thunder comes forth.<sup>62</sup> The pot must then be closed again.

#### SOTEKNANI <sup>63</sup>

It is certainly true, not maybe! <sup>64</sup> A great many people, Cloud and Eagle People, live up in the sky, where Soteknani lives. There is no sky above that one. We live on the earth; down below us is another world from which we came. Below this is still another

<sup>59</sup> See the discussion of this point by Titiev, *op. cit.*, p. 108.

<sup>60</sup> Compare N. Dumarest, "Notes on Cochiti, New Mexico," *Mem. Am. Anthropol. Assn.*, 6 (1920): 174. This reference was supplied by Dr. Parsons.

<sup>61</sup> "Not with their prayer feathers?" (E. C. P.)

<sup>62</sup> "This appears to contradict the preceding statements, which may be incorrect. That lightning and thunder are kept in pots or jars is a widespread Pueblo belief, and probably had a much wider distribution. I have found it among the Zapotecas of southern Mexico." (E. C. P.)

<sup>63</sup> "On First Mesa, Shotokünufwa is a sky god associated with stars, lightning, and war." (E. C. P.) Similar ideas prevail in all the Hopi towns. (M. T.)

<sup>64</sup> "A story is frequently introduced in this way to distinguish it from those which men think up for themselves and which need not be true. 'This is not a funny story, or one that I made for myself.'" (E. C. P.)

world where people are to be found.<sup>65</sup> Here it is dark, so dark that human beings cannot see. That is why we have moved upward all the time, but we cannot now get to the world above us.

The spirits of dead people go down into the earth. A very bad person [witch] goes away down after death. The headman of the place says to him, "Go over there!" and he is thrown into the fire. He lives no longer; he is only ashes. The waves of heat which can be seen rising from the surface of the earth in spring or summer come from the fire down there.<sup>66</sup> This is a story we must never forget. Should we forget it we will be doing something wrong, some disaster will come, and no one will be left alive in this world.

Soteknani is the name of a being who lives in the sky. The name is said to be derived from *sol'ba* ("star")<sup>67</sup> and *omawa* ("cloud"). In representing him his head is given the likeness of a star, and clouds are shown as part of his garments.<sup>68</sup> He makes it rain, lighten, and thunder. When he thrusts forth the arrow shaft which he holds in his hand, the lightning appears. We address him thus: "*Ta' ina'a ov'a katoka*" ("Oh! my father living in the sky") and tell him what we want. He gives us good things. He makes us well and strong, and takes our sickness away. He is just the same, nearly, as that fellow you white people call God.<sup>69</sup>

Soteknani knows everything. He made everything. Moiyama [Muyingwa] lives in the earth.<sup>70</sup> He gives life to the corn. Soteknani sends rain to make the ground wet; the Sun gives the warmth. After this the corn comes up and grows rapidly. Soteknani knows all about the doings of the evil men who make medicine from the flesh of dead people which they leave buried under the ground until it stinks. When this has been done, wind comes, but no rain.<sup>71</sup>

<sup>65</sup> The concept that mankind came up through four successive underworlds is widely distributed throughout the Pueblo area. (M. T.)

<sup>66</sup> Compare M. Titiev, "A Hopi Visit to the Afterworld," *Pap. Mich. Acad. Sci., Arts, and Letters*, 26 (1940): 500, and note 15. 1941. The spirits of dead witches emerge from the flames as beetles.

<sup>67</sup> "The Hopi word for star is *shotuk*." (E. C. P.) I have it as *sohu*. (M. T.)

<sup>68</sup> For various depictions of this deity see under *Shotokfinufwa* in the index to *Hopi Journal*.

<sup>69</sup> "Or Dios, as was probably pointed out by the early Spanish missionaries. See *Hopi Journal*, p. 96, note 1." (E. C. P.)

<sup>70</sup> According to Parsons, *Pueblo Indian Religion*, p. 173, Muyingwa is "the male maize spirit of the Hopi underworld. . . ."

<sup>71</sup> "In Pueblo circles wind is generally associated, as here, with witchcraft." (E. C. P.) See Parsons, *op. cit.*, p. 136, note †.

Soteknani knows where this bad place is. If others do not remove the flesh, he shoots the spot with his lightning and removes it along with any other evil thing that is there.<sup>72</sup> The Flute society members acquire power by digging at the place where lightning has struck. They follow the zigzag course that the thunderbolt has taken. Sometimes they find a stone arrowhead — stone arrowheads come from Soteknani.<sup>73</sup> The Water clan keeps all of these arrows. Its members make use of them in their prayers to Soteknani for rain.<sup>74</sup> These arrowheads are not made by Indians. If you find one, you must not pick it up. Merely turn its point toward your house, and leave it there for four days. At the end of this time take it to the village and give it to the Water clan. Sometimes "water hornets," *talangaiga* ("dragon flies"?), come out of a place where an arrowhead has been, the arrowhead having turned into water hornets. These fly up into the sky, from which the arrowhead has come.

## FOLK TALES

Sometimes my grandfather would start a story after supper and continue it through the night. "Now, my grandson," he would say, "I have a good story. Perhaps you do not want to sleep." "No," would be the reply, "I shall not sleep." Sometimes, after he had told me a tale, I would not hear it again for a long time and would forget it. That is why he repeated it. I was the only one to whom he told stories. The young people do not know these legends. The winter months from December to February are the

<sup>72</sup> "A person struck by lightning or one whose field has been hit is supposed to join the Flute society. From the association between lightning and witchcraft we may infer that the Flute society is a kind of curing society, curing bewitchment." (E. C. P.)

<sup>73</sup> "In this statement Soteknani is identified as the god of lightning. On First Mesa he is represented as a *katchina* and, as such, is a rain maker, but his rain-making character is not emphasized, as it is here. On First Mesa the Clouds, the Chiefs of the Directions, and the *katchinas* are rain makers, and it is Pukonghōya who sends arrowheads. See *Hopi Journal*, p. 137." (E. C. P.)

<sup>74</sup> "This must be the ceremony Stephen mentions in which the Patki clan chief withdraws to a cave for sixteen days at planting season to pray for rain. See *Hopi Journal*, pp. 1033-1035; and E. C. Parsons, "A Pueblo Indian Journal, 1920-1921," *Mem. Am. Anthropol. Assn.*, 32 (1925): 87, note 136.

"One of the Patki (Water) clan chiefs on First Mesa is referred to as *yui'asila*, which suggests the term for 'rain arrowhead,' *yoiashiva*, although it was otherwise translated as 'rain baptism.' The obscure reference to the ceremony he performs is illuminated by this account of the function of the Water clan chief at Chimopovy." (E. C. P.)



best time for telling stories, but they may be told at any other time of the year.

There seem to be two classes of narratives which are clearly distinct in the minds of the Hopi; the serious, old-time tale, and the story that elicits merriment. The coyote cycle comprises a large part of the latter.

### *A Navaho and a Coyote*

A Navaho went hunting. He took his wife with him. Three of her brothers went along. The party numbered five, all told. They went hunting for deer. This was near Chimopovy. Coyote went past her. He was a bad coyote. She played with him, and had intercourse with him. She told no one, not even her brothers, and she did not tell her husband.

All of them went hunting. She stayed alone at the camp. The men were not able to kill any more deer. The deer were afraid and ran away from them. That night her husband failed to return. Perhaps something had gone wrong. When the woman's brothers came home from the hunt, they smelled coyote. "Someone has been here," they said. "We smell coyote." They asked her, "Has anyone come here?" "No, no one has been here." "Someone must have been here. We smell coyote." That was why the deer were afraid, and continually ran away from them. "Maybe there is a coyote near here, and that is the reason we smell him," they said.

That night her husband does not return. The following day they find him dead, torn to pieces. The others go hunting, and after a while one of the brothers fails to return; then another one goes, and he, too, does not come back. Now only one is left. She is a bad woman. She had turned herself into a bear<sup>17</sup> and had killed her husband, because she preferred coyote for a mate. She says to the remaining brother: "Do not go away; stay here." The deer were always running away because of the odor of coyote [carried by the hunters]. Her brothers had killed coyote. She had become angry and had killed her brothers, except this one.

The one who is left stays there all the time. He gets supper and goes away. She looks for him, but cannot find him. He goes behind a cedar tree to micturate. From a little hole in the ground he hears a voice: "Do not urinate on me!" He looks around and

<sup>17</sup> Animal metamorphosis is the common practice of witches.

does not pass water on that spot. Again he hears the voice: "My grandson, come over here, I have something to tell you." He goes to the place and sees Spider. She had the appearance of an old woman, and was sitting on the edge of the hole. "Let us go into my house," she said. "I cannot get in," he replies. "Well, insert your foot and shake it." He inserts his foot, shakes it, and the entrance swings wide open, like a door.<sup>76</sup>

"Oh, my grandson," begins Spider Woman, "I shall tell you something. Your sister is very bad. She has killed all of your brothers. Tomorrow she will kill you. I know that she intends to kill you tomorrow. That is why I tell you. Watch her. It is not necessary that you hunt tomorrow. After breakfast remain with her. She will comb your hair, and then will give you something to eat. She will go behind you and turn herself into a bear. I give you this medicine. Take it with you, and she will not kill you. Otherwise she will kill you, for you will not be able to defend yourself. I shall give you this *repi*" ['crystal,' believed to have dropped from the sky]. That is how I provide for you. Lie down here, and I will prepare you; you will then not die. She will suggest something for you to do. Perhaps you will play at something with her. She is a good shot with the bow and arrow. Maybe she will beat you at the game and then kill you."

Spider Woman then took out the man's heart and put the *repi* in its place. "I give you this heart, so that you will not die," she said.<sup>77</sup> She removed his actual heart and put the crystal in its place. It was bright and transparent, like glass. The old woman thus gave him this, and he gave her his heart [for safekeeping].

He goes back to the camp and to his sister. She washes his hair and combs it. Soon sunshine is seen. Both turn their faces to the east and sing. Then she moves, saying she is too close. She is continually moving away from him. "What are you doing?" he asks. "Why are you moving back continually?" "I am not doing anything," she replies. She ties his heart [figuratively] after the manner of Navaho medicine men. He sees her shadow and

<sup>76</sup> Compare the pattern for meeting Spider Woman; see p. 541 and notes 47-49.

<sup>77</sup> See *Hopi Journal*, pp. 1286-1287, for the etymology and use of this word.

<sup>78</sup> This is another evidence of Spider Woman's dual nature. Sometimes she does harm to mankind, whereas at other times she comforts and aids people in distress. See note 47.

notices by it that she has little ears like those of a bear, and that she is opening her mouth, as if to bite him. "Ssest!" he cries. Then she goes back. She starts to bite him again. "Ssest!" he says, "what are you doing?"

"I am doing nothing." "Surely you are trying to do something; I see your shadow. Wait a minute," he says. "I want to go out to micturate." He stands up. She is a bear now, grasps him about the body, after the manner of that beast, tears him open, and throws away his entrails. She has now killed her brother. She throws the viscera over to one side near his grandmother's [Spider Woman's] house. The old lady comes out. "So it is"; she remarks, "she has killed you. I told you she would." She then gives him back his heart. She is a clever person, and she had fixed him so that he could live again.

"Go back to your sister now," she instructs him, "and enter into a contest with her. Go back, and challenge her to something. Play your part, and you will soon beat her. Then kill her. Do not shoot her. Run away, and she will run after you. Her heart is in a tree. Run fast. She cannot run fast, and will become tired and breathless. When this happens, the tree which contains her heart will wave to and fro. Take your bow and shoot an arrow immediately under the tree. Shoot there, and then, while she is far behind you, she will die."

The sister looks up and sees him coming. Her eyes grow very large [with surprise]. "Ah, my brother, who made you to live again?" "No one; I restored myself to life." He goes in and remains with her a while. "Let us have a contest," he says, "a contest with the bow and arrow." "Agreed."

They make a little mound of sand about twenty yards away from them, and in the middle they put up a little stick. (That is the way the Hopi prepare for a contest. The object is to place the arrow immediately below the stick; the closer the arrow comes to continuing the vertical line of the stick, the better the result.) He excels his sister. She is angry. In the afternoon he returns to her camp. She is cooking dinner. After dinner she again combs his hair. (He has put his bow and arrow in a spot which will be near the place to which he intends to run.) His sister combs his hair and hunts for the lice. Every time she moves she goes farther back. She behaves as she had done on the previous occasion.

He perceives this. "What are you doing?" he asks. "I am merely combing your hair." "Yes, but you are doing something; I see your shadow." She now moves farther back. He stands up and runs away. She has turned into a bear and goes after him. He runs to his weapons, picks them up, and takes them along. The bear is very close to him.

He runs a long distance into the woods, where the trees are close together. He watches them. All is still, there is no wind. After a while he sees one tree, a young tree shaking, shaking to and fro. That is where the woman's heart is hidden. He is soon close to it. The bear, his sister, becomes tired. She cannot catch him. He puts the arrow to his bowstring. She calls to him: "Oh, my brother! Do not kill me! Do not kill me! Do not shoot! Do not kill me! Do not kill me! Stop! Stop! I will nevermore hurt you."

He pays no heed to her. He keeps right on. He is close to the tree. He raises his bow and shoots the arrow. His sister cries out, like a bear. He shoots under the roots of the tree that is shaking. He hears the bear panting behind him. He looks back; the bear is lying prostrate, dead. That is how he did that time. He has killed his sister, and now he is alone. He gets his horses, packs them, and travels home to his mother. He arrives and narrates all that has happened in the woods; how his sister has killed his brothers and how she herself has died. They express sympathy for him. No one is sorry for his sister.

This is a story my grandfather told me. It is a Navaho story, but it is told by the Hopi.

### *The Coyote Man*

Lomañklioma caught a boy. This was about seventeen or eighteen years ago. Lomañklioma, who had recently been married, went far up into the mountains to hunt horses. He saw a coyote. His horse was a fast runner, and he gave chase. The coyote ran away from him as fast as it could go. Lomañklioma overtook the creature and struck it with a stick. At the same time his horse ran past the beast, for it could not turn as quickly as the smaller animal. Lomañklioma went a long way before he was able to turn. He gave chase to the coyote, hoping to tire it out, and soon it became fatigued. His brother was with Lomañklioma, and the two of them pursued the beast. They passed a cedar tree and saw a boy sitting

on the side which was opposite them as they approached. He was covered with perspiration. They spoke not a word to him, merely looked at him. It was the coyote, which had run behind the cedar tree when they had brought it to bay.<sup>79</sup> A little bundle lay to one side of the boy. The men looked at him, and he became frightened. Perspiration dropped from his face, and his lips were parched with thirst. Finally they asked: "Where is the coyote?" To this he made no reply. Again they asked: "Where is the coyote? We chased it up here and we do not know where it has gone. Are you the coyote? Are you?" "Yes." "We did not know this; we almost killed you. Why did you turn into a coyote? Where have you been?"

The boy had been hunting horses. He had a brother-in-law who knew that the boy possessed the trick of turning over and becoming a coyote. The brother-in-law had a horse; the boy had none; and the former knew that someone was in the habit of taking the horse out at night. The boy had with him a wooden hoop, to which he had fastened various things. He would go through this and become a coyote, crow, wolf, or other animal, according to the part of the hoop he had used. When he returned from his forays, he would go through the hoop again [in reverse direction] and become a man.<sup>80</sup>

These are the kind of folk we do not like. They make the people sick. The man who caught the coyote is living yet. The boy begged him to tell no one. "I will pay you if you will keep quiet." "No, I want nothing; I will not accept anything from you." (If you receive a present from such a man, you will die, and he will live.<sup>81</sup> That is what my grandfather told me.) To the other man the boy offered to give a red bead necklace; but neither of them would take anything. "Keep these things for yourself," they said to him. The boy wept and wept. His name was Talasiyesva. The men did not tell anyone, but the boy thought about the matter all the time. He became sick, grew very thin, and was about to die.<sup>82</sup>

<sup>79</sup> Compare the way in which a rabbit turns into a Hemis katchina girl when it has been chased behind a rock; see Titiev, *Old Oraibi*, p. 246.

<sup>80</sup> Compare p. 537.

<sup>81</sup> It is always dangerous to accept a witch's bribe. Compare Titiev, *op. cit.* (see note 36), p. 555.

<sup>82</sup> Sorcerers who have been identified are supposed to die soon thereafter. *Ibid.*

The two men then told the people: "We found him in the woods as a coyote. We chased him, struck him with a stick, and he went behind a cedar tree. When we went around it, there was the boy sitting down, covered with perspiration. He got up, he was not dead." After that he was sick for about a year. He was palsied and could not walk fast.

This boy died about eight years ago. No one liked him. The girls did not like him, and he could not find anyone who would marry him.

WAR <sup>83</sup>

My father and grandfather told me that a Navaho is of no account — he is just like a coyote or a crow. There is no use taking his scalp, for it imparts no medicine.<sup>84</sup> An Apache, however, is a great man. If you kill him, you can acquire his brave spirit. His scalp is removed, to the accompaniment of song. The victor, after removing a scalp, holds his knife up toward the sun, then quickly puts the knife away. To kill a Ute, Kiowa, Comanche, or Paiute will impart courage, for these are powerful men. The Paiute especially is always a hard fighter.

Before a fight medicine is made for the warriors. Silaotiwa was the first man to make it. He tied hair and spittle of a Navaho into a bundle, then began a song to bring the spirit. He placed water in a pot and put medicine in it. He thrust the bundle which he had made, as far as his arm would reach, into a hole used by red ants.<sup>85</sup> He put ashes in with the bundle, and said: "I bury you. This we do to the Navaho Indians. May there be no more around here in this world." ("The Navaho are a worthless lot, who fight all the time," said the informant.) Then he sang and sang. Masau'u, the first being on earth, cried out to him, "O-O-O-O!" (starting on a high note and descending like a dying siren whistle). Soon the moans of the Navaho were heard. From this bundle came wailing, weeping, and sobbing. You can still go to that place and hear them crying. My father has heard them.<sup>86</sup>

<sup>83</sup> A recent study of Hopi war customs appears in Titiev, *Old Oraibi*, pp. 155-163. Several additional details are given in the explanations of Plates XVIII-XX.

<sup>84</sup> "Compare *Hopi Journal*, p. 98." (E. C. P.)

<sup>85</sup> Parsons, *Pueblo Indian Religion*, p. 401, states that gravel from an anthill was kept in the pouch of the Acoma war chief.

<sup>86</sup> For more material on scalps that cry out see Parsons, *op. cit.*, p. 351.

The people said:<sup>87</sup> "That is all right. We have an efficacious medicine, the spirit of the bundle is potent." They then put a little earth in and over the opening, pounded it down, and killed all those Navaho. Over this place they piled a great deal of wood, kindled it, and so consumed all of them. My father watched and saw that soon lightning appeared on both sides of the place where the bundle had been put. Again the people said: "That is well; it is a powerful spirit." Soon it was finished.

Then Silaotiwa, the leader of the war party, said: "These are all my children; I am their father."<sup>88</sup> I think I shall succeed. I have a potent spirit. That is a good omen for us. Do not be afraid. Do not separate from each other; remain together."

They went in groups of three, four, or five, keeping aware of one another's whereabouts by shouting from time to time: "That is a good medicine, it bodes well for us. Now let us hunt the camp of the Navaho." When they had gone about a mile, someone came along. The Hopi stopped and whistled. They saw a horse running. It soon reached them. "Did you find a camp of Navaho?" they asked [the rider]. "Yes," was the reply, "we found a number of them, with a great many sheep and horses."

They start away before daylight. Koitcaba, of the Snake clan, and others go in the party. Already they hear fighting on the hill above them. They burn the Navaho camp and secure many horses and sheep, which they bring home.

When fighting at close quarters, clubs are frequently used in an effort to break an enemy's collarbone, so that he will be unable to lift or swing his arm.

#### SHIELD DESIGNS

The designs shown in Plates I-XX were executed freehand in watercolors by Joshua Humiyesva, who worked from memory. They depict patterns used on various Hopi shields known to him. Plates I-XVI were done at the Carlisle Indian School, after his return there from Philadelphia.<sup>89</sup> The remaining four, Plates XVII-XX, were painted at the University of Pennsylvania Museum.

<sup>87</sup> "Here, apparently, begins the account of an actual war party." (W. D. W.)

<sup>88</sup> Compare Titiev, *Old Oraibi*, p. 160, note 35. "A scalp taker calls his trophy his 'son.'"

<sup>89</sup> "I wish to acknowledge indebtedness to the late Mrs. William Diets (Angel de Cora) for invaluable assistance in this work. She obtained Joshua's

Every man makes his own shield, which is large enough to cover him when he kneels behind it. Warriors add to its protective value when facing the foe by throwing sand and grass into the air to the accompaniment of war whoops. While they are giving these shrill cries the open hand is vibrated against the mouth.

Hopi shields are circular, and made of horsehide or cowhide stretched tightly over a round piece of hickory wood, with the hairy side next to the frame. A hole in the middle permits the carrier to keep an eye on the field of battle without exposing himself. Some Hopi adopted, it is said, the custom of the Utes, and reinforced their shields by covering the entire surface with sheet iron, over which a skin was stretched.<sup>60</sup>

Each shield, in addition to its utility in warding off the enemy's projectiles, possesses magic power which is transmitted to its owner. This is generally derived from the design, which sometimes covers the entire convex face of the shield, and sometimes is limited to an area of eight or nine inches, as in Joshua's reproductions. Occasionally, too, the pattern has a practical value, as in Plate XVIII, where an eye is represented in order to conceal a needed aperture. Hopi shield designs, therefore, may have utility and magic power, in addition to their dominant aesthetic values.

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descriptions of the designs and forwarded them to me." (W. D. W.) All the original watercolors may be consulted at the University of Pennsylvania Museum.

<sup>60</sup> "Some shields are dark brown, with a cow's horns on either side." (W. D. W.) Compare the descriptions of Hopi shields in E. and P. Beaglehole, *op. cit.* (see note 21), p. 21.



## EXPLANATION OF PLATE I

Chock-qwi-na,<sup>11</sup> "Not Afraid." A policeman [probably war chief, *kaletaka* — M. T.], chosen from among the braves, is here represented. This specimen was carried by the leader of a war party. The decorations on top of the head (*Auruntwa*) possess potent medicine. The central design consists of a round black face, with crescentic yellow eyes, an oblong red-bordered mouth,<sup>12</sup> and a grayish-black beard. The ear ornaments are green with red pendants. Along the periphery are triangles of red, yellow, green, and blue (in irregular sequence), which stand for clouds.

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<sup>11</sup> Probably Chakwaina, a war chief who knows how to slay, according to *Hopi Journal*, p. 44, Fig. 29, *et passim*. Various related forms called *Tcakwaina* are pictured by J. W. Fewkes, *Hopi Katsinas*, Bureau of American Ethnology, Twenty-first Annual Report (1899-1900), Plate IV. (This work will hereafter be cited as *Hopi Katsinas*.) The form closest to this shield design is in the lower left of Plate IV.

Many of the patterns depicted on shields contain elements that are identical with those used in portraying Hopi *katsinas*. In the notes that accompany the figures most of the descriptions of form and color have been furnished by Titiev.

<sup>12</sup> Lips, teeth, and beard will not be specifically mentioned in later descriptions if they conform to those shown in Plate I.



Hopi shield design

## EXPLANATION OF PLATE II

He'e'e.<sup>33</sup> This picture records an ancient event. It depicts a woman who was in the act of dressing her hair when the enemy unexpectedly attacked. In this emergency she hurriedly inserted crow feathers near the middle of her head, fastened a shell ornament about the braid that hangs down on the right, and kept in place the wooden frame about which she had intended to fashion a whorl like the one on her left.<sup>34</sup> He'e'e's round black face is set against a stippled blue background. The eyes are yellow, the hair ornament at the left is green, and the ear decorations are red and green. Yellow, red, and green triangles, encircled by a black line, make up the outer border.

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<sup>33</sup> He'e'e is known in Hopi myth as a mother of all the katchinas. She is pictured in *Hopi Katchinas*, Plate XI, extreme right; and in H. R. Voth, *The Oraibi Powamu Ceremony*, Anthropological Series, Field Columbian Museum, No. 3 (1901): Plate LXVIIa.

<sup>34</sup> Fewkes, *op. cit.*, p. 63, narrates a parallel tale in which Teakwaina Mana, a warrior maiden, leaves her hairdressing unfinished in order to fight the enemy who attacked her pueblo while the men were away.



Hopi shield design

### EXPLANATION OF PLATE III

Mochini <sup>95</sup> kateina, a watchman. The user of this shield will always be on the alert against the foe. Mochini kateina has a black face with parallel white lines running about it, and eyes consisting of two concentric white lozenges. The mouth and ear plugs are red. The rim is made up principally of bands of green, blue, and black.

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<sup>95</sup> This may be the same word as that for the bird Mutcani; see p. 528. The closest approximation to this picture seems to be Teakwaina Yuadta, which is shown at the lower right of Plate IV in Fewkes, *op. cit.* It may be that Mochini is the wrong name. (M. T.)



Hopi shield design

## EXPLANATION OF PLATE IV

Hen' katchina, another watchman. He has a black face with white eyes, red lips, and a white mark on the forehead which indicates the footprint of a crow,<sup>96</sup> a bird of magic force and great wariness. The outer limit of the design is made up of alternating blue and red triangles.

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<sup>96</sup> In *Hopi Journal*, p. 341, Fig. 293, *et passim*, this element is interpreted as a snipe's footprint.



Hopi shield design

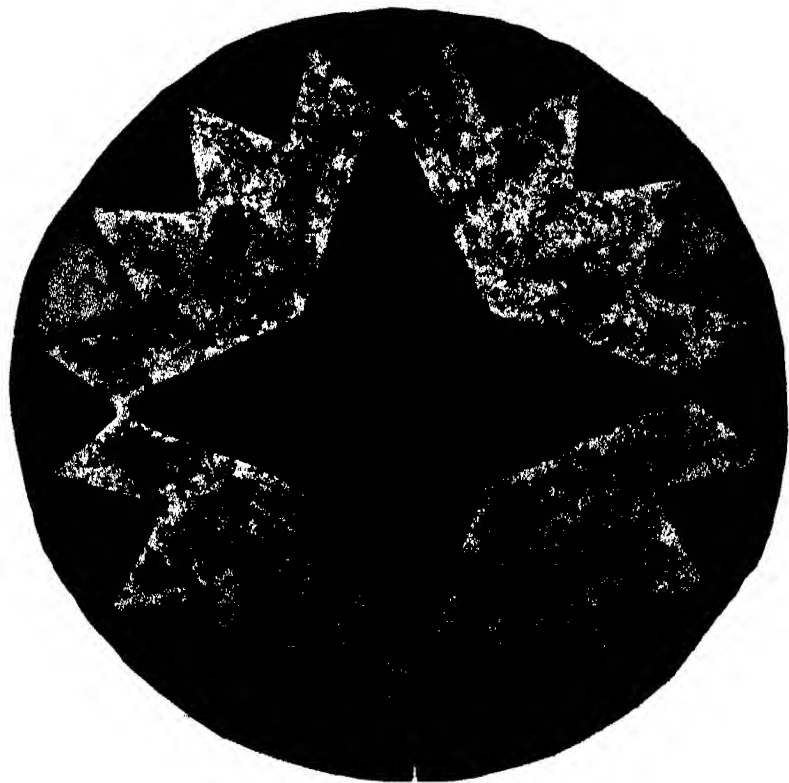


## EXPLANATION OF PLATE V

Soli'thl, "Star."<sup>77</sup> The three dark spots in the middle represent the eyes and mouth. The red star on the stippled light-blue field depicts the azure background of the sky. Blue, green, yellow, and red triangles make up the outer border.

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<sup>77</sup> Designs similar to that in Plate V are pictured as pertaining to Coto ("Star") kateina, in *Hopi Kateinas*, Plate XXVIII, bottom; in *Hopi Journal* they are variously ascribed to Taiowa (Plate Ib), "Moon's House" (Plate XIVb, c), and "Morning Star" (p. 233, Fig. 143d).



Hopi shield design

## EXPLANATION OF PLATE VI

Teua, "rattlesnake." The central figure, a black-spotted yellow rattlesnake, portrays a fighter who never leaves the field.\* It endows a man with its own qualities and spirit. The background is green and portrays grass; the triangles are blue and indicate clouds; and the opening in the rim symbolizes a means of escape for a warrior surrounded by the enemy.

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\* The militaristic character of snakes is discussed by Titiev, *Old Oraibi*, pp. 152-153.



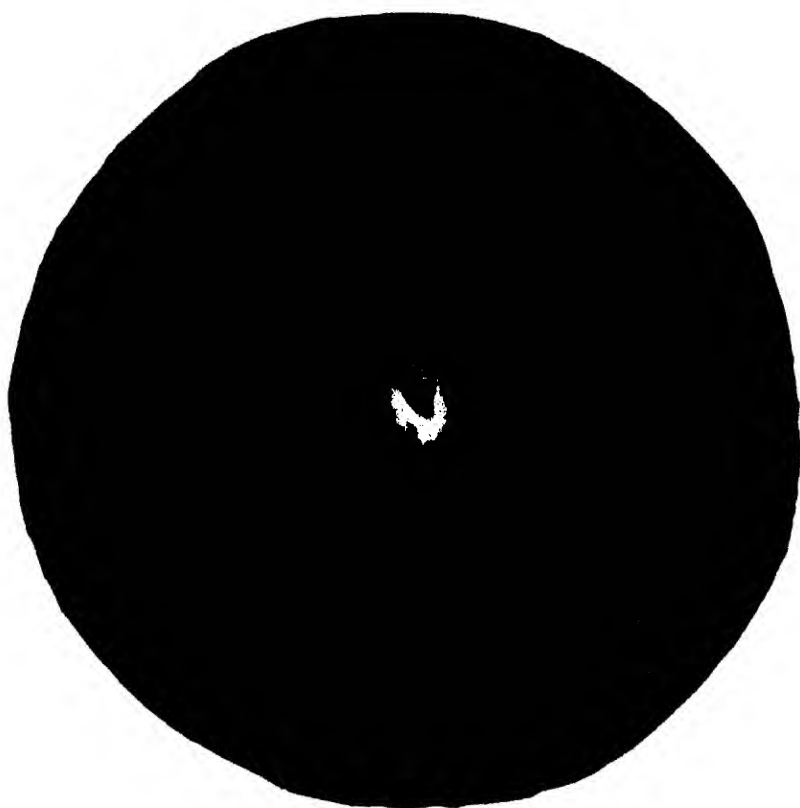
Hopi shield design

## EXPLANATION OF PLATE VII

Mongwu, "owl."<sup>99</sup> A scout with piercing eyes who goes about by night to reconnoiter the foe. A brownish-gray owl, with yellow eyes, beak, and feet, is shown on a blue field that stands for the sky. The triangles are red brown and represent the clouds glowing on the horizon in the gathering dusk of twilight.

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<sup>99</sup> The owl shown in Plate VII bears some resemblance to Mongwu Wüqti ("Owl Woman"), who is pictured at the bottom of Plate XVI in *Hopi Katsinas*.



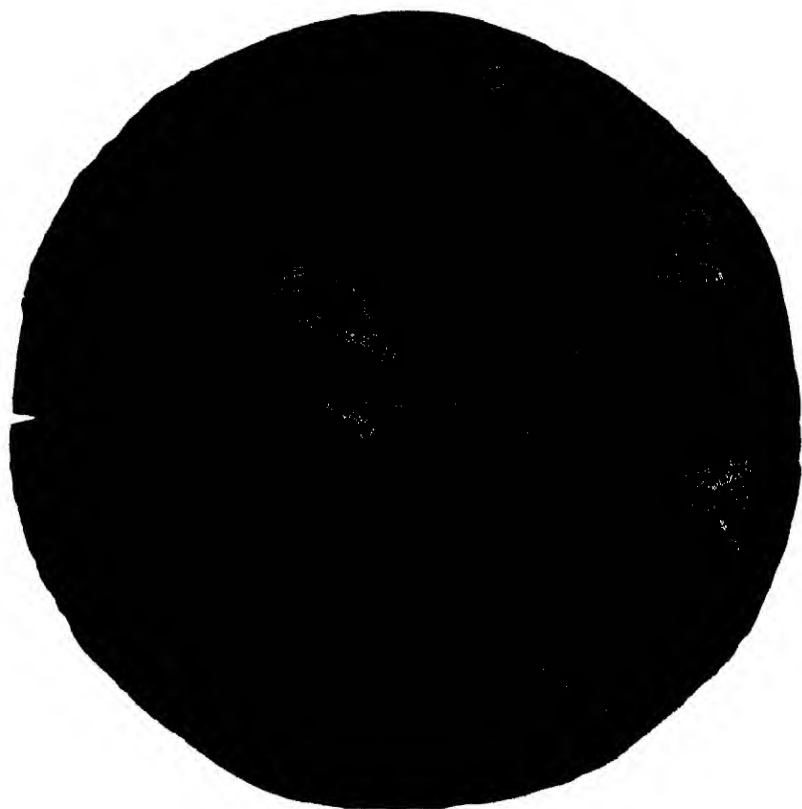
Hopi shield design

## EXPLANATION OF PLATE VIII

Inearer, "gray wolf" (?).<sup>100</sup> A gray wolf with a red eye is depicted on a blue background. He is the forewarner of catastrophe, a brave and fierce fighter who will devour the dead as well as the living. Red, green, and purple triangles depend from the rim, and the break in the outer line indicates an exit for a hard-pressed warrior.

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<sup>100</sup> The translation of "gray wolf" is *masi kweuc*. The wolf is customarily portrayed on military altars as occupying the eastern quarter. See, for example, J. W. Fewkes, "Minor Hopi Festivals," *Am. Anthropol.*, 4 (1902): Plate XXII.



Hopi shield design

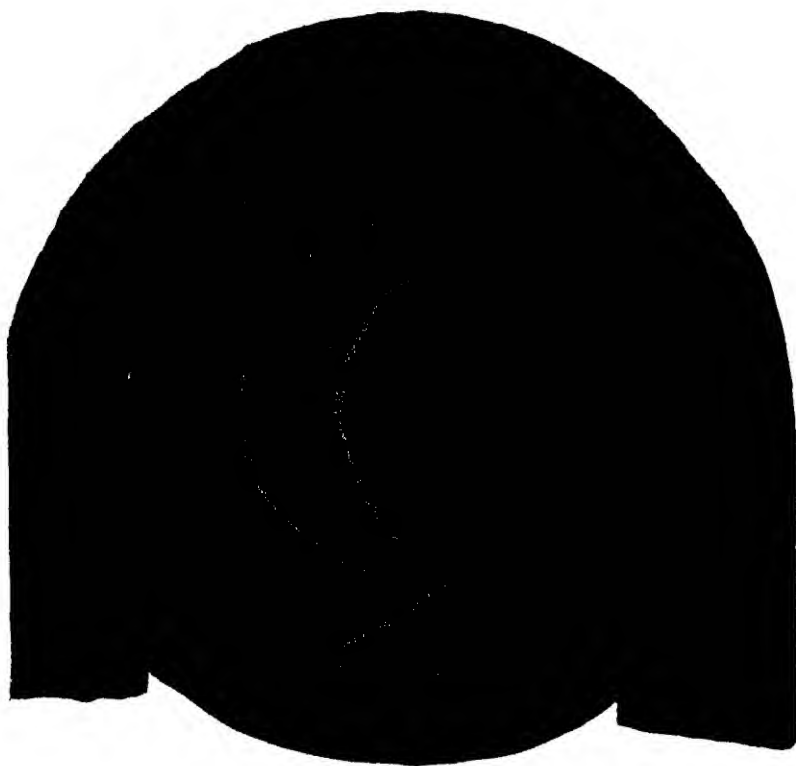


## EXPLANATION OF PLATE IX

Na-a-gwatch'sta, "making friends."<sup>101</sup> The crescents represent clasped hands, emblematic of peace and truce. The one at the left is green, and the one at the right is blue. The background is brown, and the outer border is black, red, and green.

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<sup>101</sup> The sign of *nakwachi* ("friendship") is shown on a Ute shield in *Hopi Journal*, p. 131, Fig. 83.



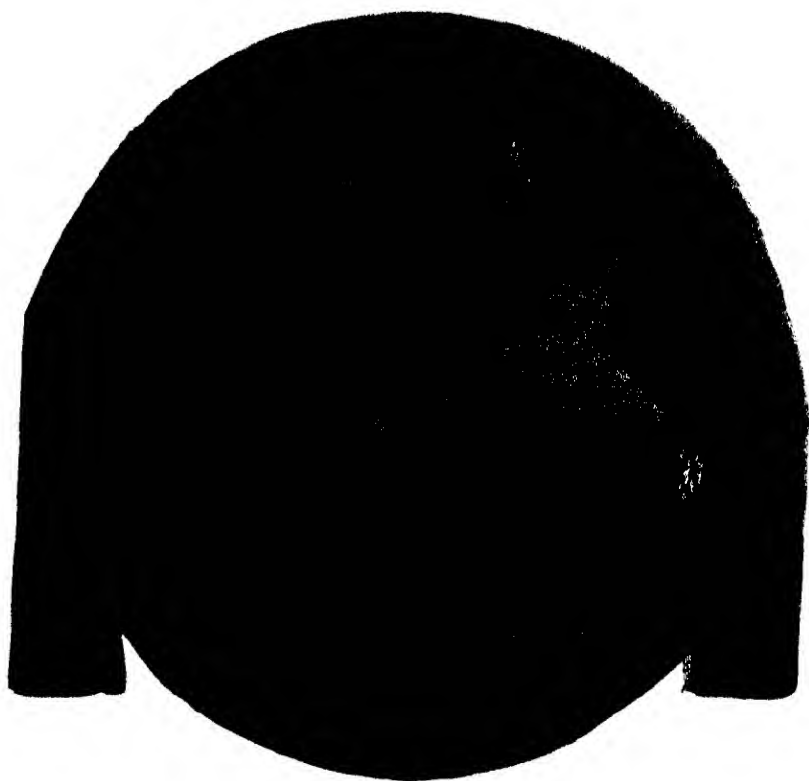
Hopi shield design

## EXPLANATION OF PLATE X

Ci-hu-wo-da.<sup>102</sup> Four triangles on a brown field radiate from a yellow hub. The horizontal ones are green with blue tips, and the vertical ones are blue with green tips. They are rimmed with lines of black, red, and green. This is an emblem of universal peace and happiness. The blossoming of the land is indicated by the central pattern. The outer ribbons and feathers are simply ornamental.

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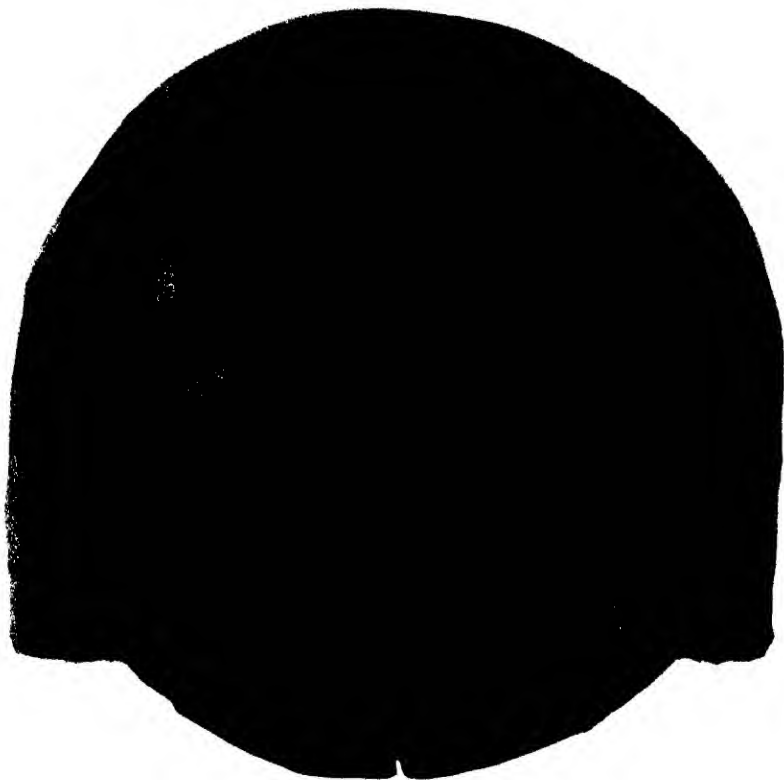
<sup>102</sup> *Sihu* ("blossom") is the basis of this word. A similar design appears on the helmet of *Cipikne kalcina* in *Hopi Kalcinas*, Plate II, upper right.



Hopi shield design

## EXPLANATION OF PLATE XI

Du-er-wo-da. A black-tipped brown spear (*lansa*) is the central figure and divides a blue field into halves. On each side a brown triangle is edged in black, red, and black. A blue star is shown on the right, and a yellow one on the left. The whole design culminates in black, red, and green lines. The tassel stands for a scalp; and the yellow and blue stars portray the evening and morning stars, respectively. This picture means that the owner is on the alert by day and night. As has been pointed out previously, the opening in the outer circle shows an exit from surrounding perils.



Hopi shield design

## EXPLANATION OF PLATE XII

Hootch'ko, "hooting owl." An owl similar to the one in Plate VII is set against a circle of pale green, ringed with dark blue. The green represents the foliage of trees, and the blue indicates the heavens. The lower border of the design is dark green (representing the ground) and black; and the upper border is green, red, green, and black. In the night the owl makes his messages known far and near, as does the whippoorwill. The calls of these birds are used for sending secret communications.



Hopi shield design

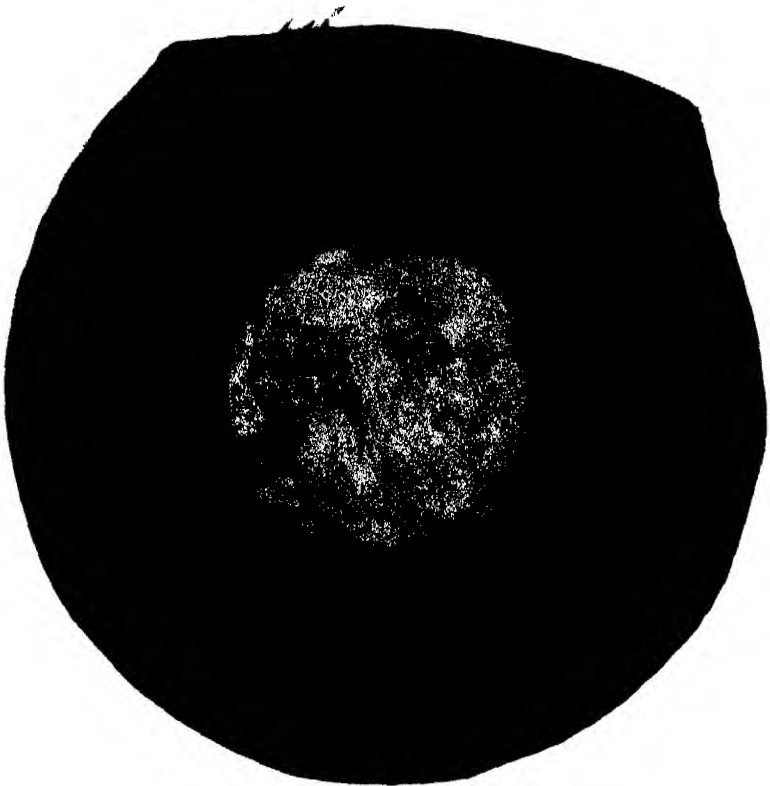


## EXPLANATION OF PLATE XIII

Mo-li-yä-wä, "moonlight." <sup>103</sup> This is of particular assistance to those who are fighting during the night. The inner circle, containing a face, is done in gray, edged with a thin line of red and a wider band of black. Around it runs a wide blue band, within which are set red stars at top and bottom, a green star at the left, and a red one at the right. The color bars of yellow, green, and red shown at each side forecast rain or shine. The outermost circle is green below, and red rimmed with blue above.

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<sup>103</sup> A variant portrayal of the moon, *märiyawu*, appears on the wall of the chief kiva in *Hopi Journal*, p. 233, Fig. 143c.



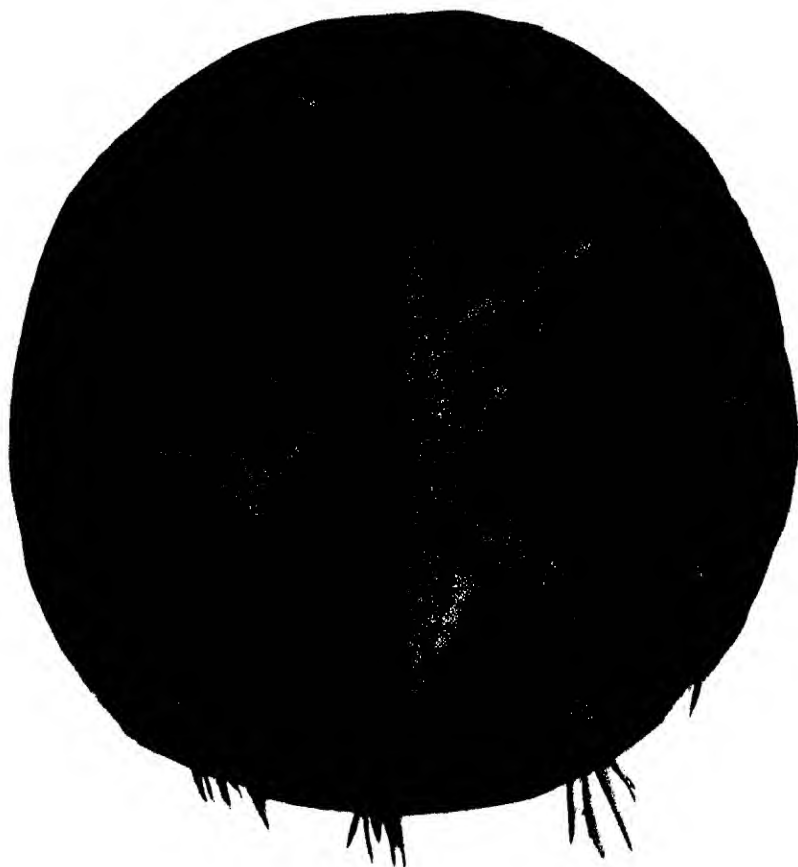
Hopi shield design

## EXPLANATION OF PLATE XIV

Na-de'rsu-hu, "guiding star."<sup>104</sup> The central design consists of a polychromatic eight-pointed star, with fields of blue, green, yellow, and red. This star is placed against a brown background, encircled by a blue line and a wide band of red edged in blue. The star is at the zenith, and is ever watchful of the Hopi. The rays that twinkle from it are messages to the people, and foretell their good or evil fortune in an impending conflict. This heavenly body is closely watched by fighters, particularly in times of war. If fine straight rays emanate from it, this means that the Hopi will succeed in taking scalps.

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<sup>104</sup> Compare the illustration of a five-pointed star on the wall of the war chief's chamber at Walpi, in *Hopi Journal*, p. 88, Fig. 64a, no. 1.



Hopi shield design

## EXPLANATION OF PLATE XV

Ga-wi-yo, "horse." A shield with this design ensures the capture of many horses from the enemy and protects one's own livestock. A blue-gray horse is depicted on a green background that represents grass. The outer border is red, trimmed with green. The brand on the animal indicates that it is owned by the Ute, traditional foes of the Hopi.



Hopi shield design

## EXPLANATION OF PLATE XVI

Tä-lä'-so, "dawn." A red star is shown overlapping a field of blue at the left and of brownish yellow at the right. The periphery is dark brown, edged with black. This is an artistic expression of the meeting of night (blue) and day (yellow), when the warriors, with uplifted hands, grasping arrow shafts pointed toward the red morning star, go forth to pray that their hearts may keep light and their arrows fly straight.<sup>105</sup>

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<sup>105</sup> The Hopi custom of facing east and praying to the sun at daybreak is known as *kuirato*. See Parsons, *Pueblo Indian Religion*, p. 179.



Hopi shield design



## EXPLANATION OF PLATE XVII

Toboa, "mountain lion."<sup>106</sup> A black-spotted, yellow mountain lion is pictured in the center on a mottled blue and gray background that stands for the sky. Color bars of yellow, green, and red are shown near the creature's mouth. The stars above are splotted with red, and represent the morning star on the left and the evening star on the right. These provide light, make the warrior's heart brave and strong, and dispel fear. A crescent moon, heavily outlined in black and flecked with red, green, yellow, and gray, also guarantees light for the shield bearer when he travels by night. Its upturned horns signify a good month. (If the points of the crescent were turned down, it would indicate high winds and bad weather.) In this instance the triangles of blue, red, and green that ordinarily denote clouds have no meaning.

Friendship marks (see Pl. IX) are shown at the left, and the crossed lines near the bottom represent the tracks of a blue jay. These are explained as follows: "You may be fighting somewhere, and upon your return you may see the footprints of the blue jay. You cannot tell in what direction the bird has been walking, for the tracks point several ways indifferently."<sup>107</sup> That is why they are used on the shield. They keep the enemy from finding the bearer's footprints and discovering in what direction he has gone."

The mountain lion in the center is portrayed because "he is strong and never afraid of anything — just like a bear, which fears nothing. That is why it is put on. It will help you, so that you will never be frightened; and, at the same time, you may frighten someone else into running away." The zigzag line in the open mouth represents teeth, the pale red shows the tongue, and the detached bars beyond the jaws indicate the breath (but see Pl. I), which is especially potent medicine.

This shield belongs to a warrior (*kalelaka*), but anyone may use the design.

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<sup>106</sup> The mountain lion is listed as one of the pets of the war god in *Hopi Journal*, p. 307, note 1. It is associated with the east in military rituals, and is thus pictured in Fewkes, *op. cit.* (see note 92), Plate XXII.

<sup>107</sup> The same trait is attributed to the chaparral cock or road runner, in Parsons, *op. cit.*, p. 233, note \*.



Hopi shield design

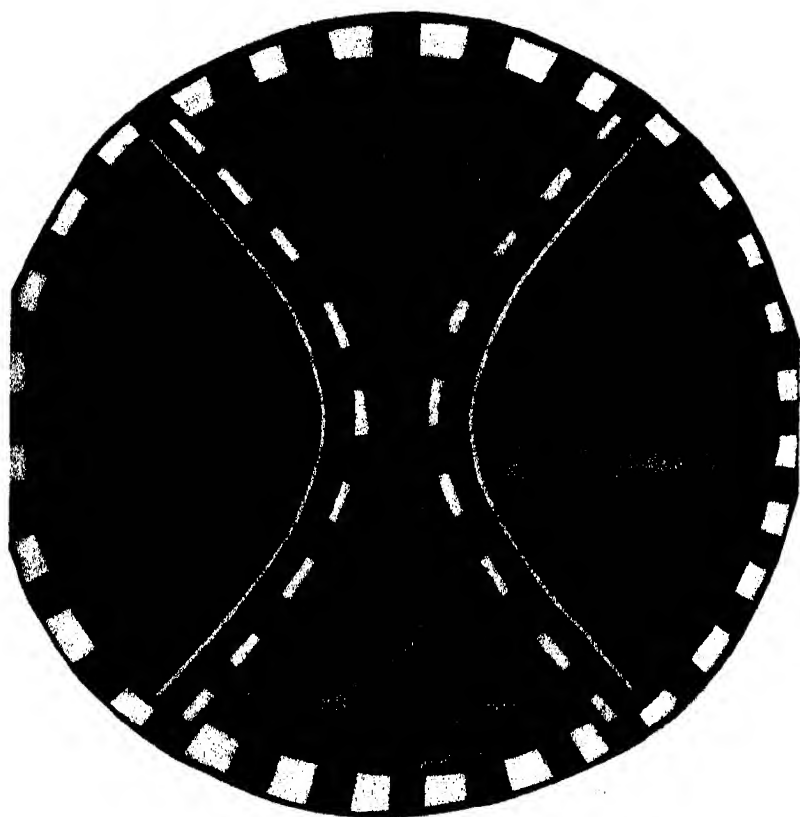
## EXPLANATION OF PLATE XVIII

Kipo'k kateina, war-cry kateina.<sup>108</sup> Curved parallel lines of black and white, red, black, white, and red set two brown fields apart from a central background of green. The kateina face here depicted bears a resemblance to the human countenance. Two eyes (of green, with black slits), the mouth, lips, teeth, and tongue are indicated. The eyes conceal apertures which allow the carrier to see through the shield while he protects his face and the upper part of his body. There is also an opening at the mouth, through which the tremulous war whoop can be emitted. The flower at the top, *hesi* ("tulip"),<sup>109</sup> is a solid red ball surrounded by green and red circles. The ornament at the bottom is painted in blue, yellow, and red.

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<sup>108</sup> This name is derived from *kihpo* ("war cry"). See *Hopi Journal*, p. 1230.

<sup>109</sup> In *Hopi Journal*, p. 1216, *hesi* is identified as the tulip *Calochortus Nuttalli*.



Hopi shield design

## EXPLANATION OF PLATE XIX

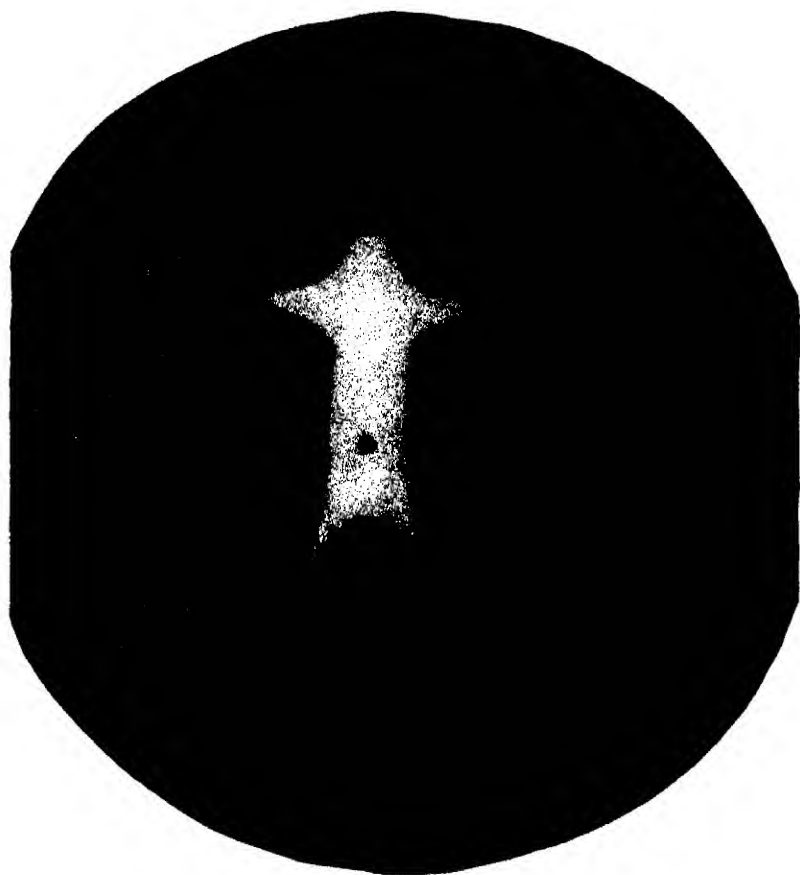
Honau, "bear."<sup>110</sup> "A strong fellow, never afraid of anything. That is why he is put on the shield. It makes the warrior like a bear in courage, and everyone will be afraid of him. When a bear is angry, no one can withstand his ferocity. His fur lies flat on his body, and arrows will not penetrate his hide."

The main figure depicts on a mottled green background a brownish-black bear, with blue eyes, red mouth, and white underbelly. Red, green, and blue triangles depend from a black rim.

The bear is represented in upright posture because he is thus always ready for action. His tracks, on either side of the main figure, frighten those who see them. "Perhaps you may go into the woods and see only traces of the beast. Suddenly he may jump from behind the bushes and scare you. For this reason the tracks are included in the design. It frightens the enemy as though a bear were walking up to him."

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<sup>110</sup> The bear is also a pet of the war god, according to *Hopi Journal*, p. 307, note 1. The use of bear fetishes in a military context during the Snake society's rituals is described on pages 699-700 of the same work.



Hopi shield design

## EXPLANATION OF PLATE XX

Kwahu, "eagle."<sup>111</sup> A grayish-black and white eagle is shown on a stippled blue field. Its beak and feet are trimmed with yellow, and its tongue is red. The evening star on the left and the morning star on the right are spotted with three large black dots, and numerous smaller ones of red, green, and yellow. They give the warrior a bright heart (i.e. high spirits), and protect him from getting lost. The three large spots in the stars represent eyes and mouth, and are so arranged as to enable the bearer to peer through an opening on each side. The bow and arrows give power to the fighter's weapons,<sup>112</sup> and make his arrows go fast and straight. The peripheral circles, from the inner side out, are done in pink, green, yellow, red, green, and black. They represent the rainbow, whose efficacy derives from the fact that one can never catch up with it since it moves away as one goes toward it. So will the owner of the shield elude his pursuers. As in other designs, the openings in the outer rims provide escape from dangerous situations.<sup>113</sup>

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<sup>111</sup> The eagle is another of the war god's pets, as stated in *Hopi Journal*, p. 307, note 1. A representation similar to that in Plate XX occurs in J. W. Fewkes, "The Use of Idols in Hopi Worship," *Ann. Rep. Smithsonian Inst. for 1921* (1924): 390, Fig. 6b.

<sup>112</sup> "Hopi warriors generally carried two bows because a weapon sometimes became worn and weak during a long fight and because time did not permit the mending of a broken bowstring." (W. D. W.)

<sup>113</sup> To prevent illness or to avoid death pottery makers often leave breaks in their designs. Compare Parsons, *Pueblo Indian Religion*, pp. 91, 93 and note \*.



Hopi shield design





## NOTES ON THE ETHNOBOTANY OF THE KERES \*

LESLIE A. WHITE

THE material presented here was obtained on numerous field trips to the Keresan pueblos of New Mexico between 1926 and 1941. The acquisition of much of it was incidental to studies of social organization and ceremonialism. Some, however, was sought systematically for its own sake. I am not a botanist, but I have had competent technical assistance in this study from Mr. Volney H. Jones, of the Ethnobotanical Laboratory in the Museum of Anthropology, University of Michigan, to whom I am greatly obliged.

Our notes include Keresan Indian names of plants, their scientific names, data on their uses, both magical and practical, and some native beliefs concerning plants. Many identifications were made by Indian informants from specimens in the Ethnobotanical Laboratory. Others were determined from plants I collected in the field. The numbers accompanying plant names are catalog numbers of specimens I obtained and deposited in the Museum of Anthropology, University of Michigan. All scientific identifications were made by Mr. Jones. Most of our information comes from the eastern Keres, although some is from Acoma.

I use the simpler system of transcription as given in "Phonetic Transcription of Indian Languages" (1, pp. 2-5) for writing native terms:

|   |                     |   |                  |
|---|---------------------|---|------------------|
| a | as in <i>father</i> | ɑ | as in <i>but</i> |
| e | as in <i>fate</i>   | ɛ | as in <i>met</i> |
| i | as in <i>pique</i>  | ɪ | as in <i>pin</i> |
| o | as in <i>note</i>   | ʊ | as in <i>put</i> |
| u | as in <i>rule</i>   | c | = sh             |

a is intermediate b-p; ɑ, intermediate d-t; ɔ, intermediate g-k. Aspiration: ' ; glottal stop: '. The elevated dot indicates that the preceding vowel is prolonged.

\* Some of the data presented here were obtained on field trips supported wholly or in part by grants from the Horace H. Rackham School of Graduate Studies, University of Michigan, to which grateful acknowledgment is here made.

## GENERAL TERMS

All kinds of plants, both wild and cultivated, that serve as food are designated by the generic term gawai'-'ait'. This word occurs frequently in prayers; the gods are asked for rain, health, long life, and gawai'aiti.<sup>1</sup> All wild plants used for greens are gótiyamunyi. Flowers are akutc; leaves, masá-nyi. Pollen, used ritually as a vehicle of prayer and mentioned often in prayers, is h'á-dawe.

## LIST OF PLANTS

Whenever we have the requisite data we present the common name first, the scientific name next, then the catalog number, and, finally, the native Indian term, or terms, and any other information that we may have on the plant in question.

Amaranth, *Amaranthus paniculatus*, ci'ibai. The seeds are called cistai-ya. They are used to bait snares to catch wi'-ck'a (Western Robin, *Turdus migratorius propinquus*) and "snow birds" called si-ya (identified by one informant as White-crowned Sparrow, *Zonotrichia leucophrys*, which may be an error, since this is not a snow bird). The leaves are eaten as greens. Mr. Jones once saw a patch of amaranth growing in a garden at Ranchitos (Santa Ana) alongside tobacco, which suggests a ritual use.

Apache plume, *Fallugia paradoxa*, 23883, a-teti; used for arrows and brooms.

Apricot, *Prunus armeniaca*, grown at most of the Keresan pueblos; eaten fresh and dried for winter use.

Bean, *Phaseolus acutifolius*, 23787, from Sia, where it is called suramak; at Santa Ana it is si'-ram. At Sia the Koshairi make a flour of this bean for ritual purposes; no other person or group is permitted to do this. At Santa Ana the ditch boss, and he alone, prepares flour of this bean, with which he prays to the spirits of the irrigation ditches night and morning (18, pp. 105-106). In a tale of the emergence the cicada asks for prayer meal of this bean in return for his services (18, p. 90). Prayer meal ground from beans is exceedingly unusual; it is almost always made from corn.

Bean, broad, *Vicia faba*, 23788, from Santo Domingo, where it is called by its Spanish name, *haba*.

<sup>1</sup> If a native term is used more than once I shall spell it phonetically on the first occurrence only.

Bean, kidney, *Phaseolus vulgaris*, 23789, from Sia; 23790, from Santo Domingo; 23791, from Jemez.<sup>2</sup> The Keresan name is gánami.

Bearberry, *Arctostaphylos Uva-ursi*. Our Santa Ana informant "could not remember" the Keresan name,<sup>3</sup> but gave the Spanish name, *kasador*. The leaves of this plant are mixed with native-grown tobacco for smoking — a rather widespread practice.

Bear grass, *Nolina microcarpa*, 23882, h'á'ac, used to make baskets.

Bee plant, Rocky Mountain, *Peritoma serrulatum*, 23903 and 23917, from Sia. This is an interesting and important plant about which ethnologists ought to know more. The names by which it is designated in unrelated Indian languages resemble one another closely.<sup>4</sup> They also resemble the Spanish name, *guaco*, which suggests that the Indians borrowed their words from the Spaniards. But the plant is indigenous and, to judge from its importance in native culture, it must have had a name in each Indian language before the coming of the Spaniards, who, until their arrival in New Mexico, had no word for it.<sup>5</sup>

The plant is boiled and perhaps mixed with some other ingredient to make the black paint used in pottery decoration. The ripened seeds are cooked and eaten; the leaves are cooked as greens. Members of the Cikame society among the Keres and of the Shivanakwe society at Zuñi are prohibited by religious injunction from eating the bee plant and the meat of jackrabbit (9, pp. 22, 397, 432).

Bush morning-glory, *Ipomoea leptophylla*, 23916, from Sia, where it is called gácace. The name connotes "something big." The plant has a large woody root, which is dried, ground, and put into water for mares to drink to promote fertility. It is also given to colts to cause them to become large horses. The root is used also to make the hindquarters of the little hobbyhorse "ridden" by saints in ceremonial impersonations (17).

<sup>2</sup> Jemez is a Tanoan, not a Keresan, pueblo. I obtained considerable plant material from this village also.

<sup>3</sup> When an informant "can't remember" the native name of a familiar object it often — but not always, of course — indicates that the thing in question is sacred and that he does not wish to divulge any information concerning it.

<sup>4</sup> The Keres call it wa-k'o; the Tewa, qwa (10, p. 10); the Navajos, wa- (24, p. 34); wha-o-na at Taos (23, p. 25).

<sup>5</sup> Some thirteen plants listed by Martinez (8) in his *Catálogo* are called "guaco," but none is *Peritoma serrulatum*. The plants which he terms "guaco" belong to the families of Aristolochiaceae and Compositae; *Peritoma serrulatum* belongs to the family Capparidaceae.

Cactus, *Opuntia*, ibanyi. If one asks an informant for "the name of cactus," he will almost invariably give ibanyi. Other names are listed below.

Cactus, cane, *Opuntia arborescens*, ibanyi.

Cactus, hedgehog, or fishhook, *Echinocactus*, i'macot.

Cactus, prickly pear, *Opuntia Lindheimeri*,<sup>6</sup> ibitca. This species is eaten; "we make a big bonfire, burn off all the thorns, roast it in damp sand, and eat it with chili," said an informant.

Cantaloupe, *Cucumis Melo*, 23800, from Sia, 23792-94-95, from Santo Domingo; 23796-97-98-99, from Jemez. The Keresan call it mero-nyi — a corruption of the Spanish *melón*. Various foods, especially rabbit stews, are flavored with cantaloupe seeds. Before being used they are ground on a metate to remove the shells.

Cattail, *Typha latifolia*, 23896, from Sia. There is some confusion regarding the Keresan name. A Sia informant called it á-suna. One Santa Ana informant also called it asuna, but another termed it átcuwa. One of them may have confused "cattail" with "bulrush" (*Scirpus*). Cattail "fuzz" is called wa-bócten, and is used down; it is used ritually after the manner of prayer medicine.

Chenopodium, 23894. The specimen was obtained at the Spanish village of San Ysidro, where the plant is called *quelite* and is eaten as greens. It has a similar use among the Keres. It is called *chili* at Sia.

Chick-pea, *Cicer arietinum*, 23896, from Cochiti, where it is known as ctó'owina, as well as by its Spanish name, *garbanzo*.

Chili, *Capsicum annum*, 23783, from Domingo, 23786, from Sia, 23784-85 from Jemez; called by its Spanish name, *chili*. It is grown extensively and is usually eaten in stews.

Clover, prairie, *Petalostemon oligophyllus*, 23913, from Sia, where it is called h'o-nyi (no English equivalent) wa-wa ('medicine'). The root is chewed in the spring before the leaves come out; it is very sweet and juicy at this time.

Coriander, *Coriandrum sativum*, 23849-50-51, from Jemez pueblo, where it is called by its Spanish name, *culantro*. The seeds are used, by Indians and Spanish alike, to flavor soups and stews. The Keresan name, if there is one, was not obtained.

<sup>6</sup> Identification was made in the laboratory from this species, although it does not grow near Santa Ana. It is quite similar, however, to the species near that pueblo.

Cotton, *Gossypium*, 23852, from Domingo, a plant with open pods containing lint; 23854, from Sia, lint and seeds only; 23853 and 23855, from Jemez. This is, in all probability, the aboriginal cotton, *Gossypium hopi* (15). It is called ci'puk'<sup>o</sup> at Santo Domingo; ci-bo at Sia, ci'-bo'ok'<sup>o</sup> at Santa Ana. The Jemez name was not ascertained.

Cottonwood, *Populus*, h'i'-terai'i.

Fir, balsam, *Abies concolor*, 23900, from Sia, called hénati ('clouds').

Gourd, cultivated, *Lagenaria siceraria*, 23846, from Jemez; 23847-48, from Sia; the Keresan name is gya-wi. One of these, 23847, is a large gourd with a neck; it is used to make dippers and rattles. Occasionally gourds are boiled to soften them, then filled with hot sand and molded into the desired shape.

Gourd, wild, *Cucurbita foetidissima*, 23881, from Sia, where the native name is sti-tc.

Greasewood, *Sarcobatus vermiculatus*, 23901, from Sia. There is uncertainty regarding the Keresan name. A Sia informant called it wá-cba; a Santa Ana, a-tca. But our Sia assistant also called saltbush washpa (see below). There has been much confusion regarding the meaning of washpa: Stevenson renders it "cactus" (12, p. 19); Hodge, "dance kilt" (6); Bandelier, "buffalo grass" (22, 2: 216); Starr, "Mexican sage" (11, p. 42).

Hackberry, *Celtis reticulata*, 23891, branch and leaves, found a mile or so north of San Ysidro. A Sia Indian took me to the tree to inquire what it was; he said it was not known to him.

Juniper, *Juniperus monosperma*, 23885, from Sia, k'á-nyi. The berries, yó-stya, are eaten.

Juniper, Rocky Mountain, *Juniperus scopulorum*, 23905-06, from Sia, h'ase-tca. Juniper berries are eaten raw by hunters while out in the mountains, but they are better when cooked.

Lichens, *Physcia* and *Teloschistes*, k'á-wina. A shade of green is called kawina guicgunyi (19, p. 560).

Licorice, wild, *Glycyrrhiza lepidota*, ináčv. It is soaked in water and used as a bath to cure chills.

Limoncillo (Sp.), *Pectis* sp., identified from description only. It is called k'á-po at Santa Ana. There is a character in a Laguna myth called Kaponako (-nako indicates that the person is a woman); she is the mother of Sun Youth (2, pp. 87, 99, 153).

Locoweed, *Astragalus* sp., 23895, from Cochiti, where it is called k'ánadyai'ya ('witch') ck'oru-na ('pea'). Our informant said "it makes horses crazy if they eat it; sometimes it kills them."

Mahogany, mountain, *Cercocarpus* sp., 23897, from Sia, dyá-pi. All informants tell of the fondness of deer for the leaves of this shrub. A red dye for staining moccasins is made from it.

Mint, *Mentha canadensis*, 23912, from Sia, tsiti'si; used as a tea to treat fevers.

Nightshade, silver, *Solanum elaeagnifolium*, ésk'a. A brew of this plant is drunk by nursing mothers to sustain the flow of milk. The so-called Jerusalem cherries worn as a necklace by the Koshairi (18, p. 130) are the fruit of this plant.

Oak, *Quercus*, 23907, from Sia, h'á-banyi.

Peach, *Prunus persica*, 23874-75, 23879, from Jemez. The first two numbers are for seeds; the third is for fresh ripe fruit, preserved in alcohol in the Museum of Anthropology. Peaches are grown by the Keres; they are eaten fresh and are dried for winter use. No specimens from the Keresan pueblos were obtained, however.

Peas, *Pisum sativum*, 23792, from Sia, cko-ro-na.

Pine, yellow, *Pinus scopulorum*, 23910, from Sia, h'á-nyi.

Piñon, *Pinus edulis*, 23884, from Sia, dyai'ts. Piñon nuts, dyeya'anyi, are gathered in large quantities, roasted, and eaten during the winter.

Potato, wild, *Solanum Jamesii* and *Solanum Fendleri*. Potatoes were eaten, but only in times of extreme scarcity, it would appear from an Acoma account (20, p. 330). When eaten raw they were mixed with clay to counteract their vigorous astringent effect; they were also boiled with clay. Potatoes are not cultivated by the Keres. An Acoma once told me that they were not cultivated because they would not grow there. "Did anyone ever try to raise them?" I asked. "No, no one ever tried, because they won't grow," he replied.

Pumpkin, *Cucurbita maxima*, 23843, from Domingo; 23844 from Sia. The Sia call this merikana ('American') dányi since it is not indigenous to their part of the country. They call *C. moschata*, which is indigenous, dówai'mi ('native') dányi when they wish to distinguish it from *C. maxima*.

Pumpkin, *Cucurbita moschata*, 23842, from Domingo; 23845,

from Sia, seeds from a large pumpkin with greenish-black stripes. The Keresan name is dányi.

Rabbit brush, *Chrysothamnus* sp., 23902, from Sia, where it is called k'o-ya ('woman') baba ('grandparent'); a Santa Ana informant called it átsana. It is soaked in hot water and drunk as an emetic; it is "good for stomach trouble."

Saffron, bastard, *Carthamus tinctorius*. A Santa Ana claimed that he knew of no name for it, Indian or other (it is not a native American plant). He stated, however, that a certain man at his pueblo grew it in his garden, but for what purpose he did not know — which leads one to suspect a ceremonial use.

Saltbush, *Atriplex canescens*, 23911, from Sia, wá-cba. As previously noted, greasewood has been identified as washpu.

Skunkbush, *Rhus trilobata*, called gyá-pi by one Santa Ana informant; ya'ana, by another. The berries are eaten; the leaves are dried and mixed with native smoking tobacco.

Snakeweed, *Gutierrezia* sp., 23909, from Sia, cpé-motcra. The plant is soaked in water, which is drunk as a ritual emetic during retreats and before rabbit hunts. At Santo Domingo cpemotcra is said to be "an old name for Domingo" (13, p. 205).

Spruce, Douglas, *Pseudotsuga mucronata*, 23899, from Sia, h'á-kak. This is an important tree mythologically; it figures in the myth of emergence, where it is called hé-yac ('fog') (18, p. 91). It is important ritually, too, being used in the costume of dancers, for the manufacture of prayer sticks, and for other purposes.

Sunflower, *Helianthus* sp., hi'eti.

Tea plant, *Thelesperma gracile*, 23914, from Sia, where it is called go-ta, which may be a Spanish word. The leaves are boiled to make a tea which looks like our tea and is said to be very good. Sometimes the roots, too, are boiled. As Jones (7) has shown, a beverage brewed from this plant was widely used in the Southwest.

Tobacco, *Nicotiana rustica*, h'a-mi. Specimens were obtained at Santa Ana, Santo Domingo, Cochiti, Jemez, and San Ysidro. The plant I secured at Santa Ana in 1934 was the first to be identified scientifically from the Keres, or, in fact, from any of the New Mexico pueblos, so far as I know. It turned out to be a species that, according to earlier authorities, was not supposed to be in the Southwest. This discovery led to considerable investigation and subsequent publication (14, 16, 21, 3).



Watermelon, *Citrullus vulgaris*, 23801-02-03-04-05, 23840-41. It is commonly called mero-ni, a corruption of the Spanish *melón*, but a Sia said that in his pueblo it is called kacni'-ra (i.e. Castilian; the Keres call their Spanish-speaking neighbors kacdira) danyi ('pumpkin'). Our specimens consist of seeds as follows: 23801, black seeds from Santo Domingo; 23802, tan seeds with brown margins, from Domingo; 23803, brown seeds with yellow tips, taken from a small dark-green melon; 23804, black seeds from a spherical melon, five inches in diameter, green outside, pink inside; it looked like a watermelon but did not taste like one; 23840, tan seeds with black tips, from Jemez; 23841, black seeds from Jemez; 23805, brown, mottled seeds from Sia.

Wheat, *Triticum vulgare*, 23856-57-58, from Jemez; 23859, from Santo Domingo; called acányi by the Keres. Acanyi appears to be the generic term for "grass" which has been applied specifically to wheat.

Willow, *Salix* sp., called hutck'awa and also ciyaiya; why there are two terms was not learned. Willow is used extensively in making prayer sticks.

Yucca, *Yucca baccata*, h'á-dyinyi. This is said to be the best of the soapweeds for washing hair. The fruits, hó-ckanyi, are eaten.

Yucca, *Yucca glauca*, 23888, from Sia, h'á'actca.

#### UNIDENTIFIED PLANTS

1. A plant called a-kwi or "sage" by a Sia informant. It is soaked in water, which is drunk as a ritual emetic before rabbit hunts.

2. Specimen 23887, a piece of root called cká'ua. It is soaked in water, which is used to bathe newborn babies to make them grow big and strong; this ritual is performed by the baby's father's father or by his own father. Colts, too, are bathed with this medicine to make them grow large.

3. Specimen 23886, part of a stalk of a plant which grows at the foot of wa-yu (a bird) ko-t ('mountain') near Valle Grande; it attains a height of three or four feet. The Caiyaik (Hunters' society) gather it for ritual use. Hunters obtain bits of it from the Caiyaik before going out to hunt; they chew it and rub it on their hands and faces to help them kill deer.

4. Specimen 23915 from Sia; called eko-maik'o; a plant with a

conspicuous four-petaled flower. It is used to make a yellow paint for decorating kachina masks. It is also mixed with another plant and an unidentified mineral to prepare a medicine called *gáoctca* ('sour') *wa-wa* ('medicine').

5. Specimen 23894 from the Mexican village of San Ysidro, where it is called *pagé*. The plant is composite with terminal heads and finely dissected leaves. At Sia it is called *dá'ip*" (no English equivalent) *wawa* ('medicine'). It is used by the Spanish and the Indians alike as a medicine to treat stomach disorders.

6. Specimen 23908 from Sia; called *basótl'*. It has coriaceous, spiny, holly-like leaves. The name closely resembles, if it is not identical with, the Spanish name of a plant obtained at San Ysidro: *pasóte*, 23890. This, which resembles the *Chenopodiaceae*, has a strong smell and taste of formic acid. The Mexicans use it for flavoring food.

7. A plant called *ci'pewi*; "it grows in the sand near Acoma." Starr identified it as "*sage*" (11, p. 42).

#### WORDS ASSOCIATED WITH CORN

If one asks a Keresan Indian, "What is your word for corn?" he will almost invariably answer "*yá-k'a*." This is the most general term for "maize," but there are many other words which mean "corn." It has often been noted that a people is likely to have an extensive vocabulary for things which play an important part in their social life. Arabs have scores of words for "camel"; the Eskimos have many for "seal." Similarly, the Keresan Pueblo Indians have a rather rich vocabulary for the most important thing in their culture — corn. We present here some data on terminology, uses, and specimens.

Specimen 23860, loose kernels of blue flour corn from Sia, called *guicgunyi* ('blue-green') *yaka* ('corn'); it is the corn commonly used to make wafer bread ('*matsinyi*'). No. 23861, *kotcinyi* ('yellow') *yaka*; 23863, kernels of large white dent corn called *merikana* ('American') *gá-cya* ('white') *yaka*; both from Sia; the latter is said to be "an early sweet corn." No. 23864, white flour corn; 23865, a small ear of dent corn; 23866, two large ears of corn in the husk, white with scattered blue and purplish kernels, all from Santo Domingo.

We have corn from Sia, 23862, which they call "*popcorn*,"

wá-ct\*. It is not true popcorn (*Zea mays everta*), but flint corn. One man is said to grow it at Santa Ana, according to an informant who stated that it is called tsácgunyi (which means 'parched corn'; see below) before it is popped; stá'wa, after.

Cpinyinyi was translated "popped corn" at Santo Domingo (13, pp. 51, 137-138). At Acoma the Arizona white-tailed deer is called cpinyinyi ('sweet corn') dyá'nyi ('deer') (20, p. 356). At Santa Ana cpinyinyi is "a dancer who gets out in front of the group of dancers in Aowe and dances by himself." In Cochiti, spenyenyi are dancers who take part in the ayahenatse ceremony (5, p. 109; 4, p. 184).

The whole corn plant growing in the field is called háwiterana. When corn is mentioned in ceremonial songs, as it frequently is, this is ordinarily the word used; in this context hawiterana has the sense of "corn maidens." When corn ears begin to form, the plant as a whole is called tsá-mot'. The young ears, however, are termed yá-munyi; but when they are large enough to roast they are called ki'nati. A perfect ear of corn, fully kernalled to the very tip, is known as kotóna; it forms the basis of the most sacred fetish of the Keres — the iariko. Iariko, or Iutiku, is the name of the mythological "mother of all the Indians"; but the term is applied to the corn-ear fetish as well (18, pp. 18, 339-340). Kotonas figure in myths and tales, where they have magic power, being able to talk and to do other marvelous things. Shelled corn is ya-tcni; but "shelled corn lying on the ground after a pile of ears has been removed" is called yátigiyama. A storeroom for corn is kositicoma.

The parts of the corn plant have names. The stalk is wá-k'a; corn silk, yá-baci; the tassel, átcnyi; corncob, yóckoma. Corn husks are ordinarily called tsiwadyadáwi, but when they serve as cigarette wrappers for ritual use they are called di-ckama.

Corn ears, roasted in a pit and stored with the husk on, are haterunyi. Green or ripe, corn on the cob without the husk, after being roasted on hot coals, is tsa-yawa'nyi. In an Acoma tale roasted sweet corn is called tsateruc (20, p. 343). Parched corn is tsacgunyi; hominy, ya-testawa. Green corn on the cob cut into small pieces and boiled is ya-k'astawa.

Ordinary corn meal for cooking is called o-petanastányi. For corn meal used in ritual contexts, however, there are two words: petana is the secular word, sūtranaiya gaco, the ceremonial term.

Sutranaiya means "our mother"; no English equivalent was obtainable for gaco. There are two terms also for a fine flour made of corn and used ritually; ckvrina is the secular, i'nawi, the ceremonial, term.

A thin uncooked gruel of corn meal is háyanyi. A thick corn-meal mush, cooked without salt, is hótcaotsi; it is the only food permitted during religious fasts. Sweet corn, parched, then ground fine and parched again, is used to make a drink called h'a-di. It is sweet and nutritious, drunk hot or cold. In the old days the Pueblo Indians drank hadi as they now drink coffee. Shelled corn (or wheat) is allowed to germinate and is then mixed with hadi to make a drink called yá'ack'a.

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# **ECONOMICS**



## EVALUATION OF PRICE CONTROL BY THE OFFICE OF PRICE ADMINISTRATION

EDGAR H. GAULT

ANY evaluation of the control of prices by the Office of Price Administration should consider the framework of economic, political, and social conditions within which it operates. It is essential for the price level to be kept on an even keel and at the same time for individual prices to be adjusted in such a way as to secure the desired or maximum output of goods needed for carrying on the war or for civilian use. Mistakes in setting prices may result in stopping or curtailing output of important items, the destruction of partially completed products, or the loss of products within the marketing system. Current examples of the effects of faulty pricing are found in the plowing under of vegetables in Louisiana by farmers who were not satisfied with the government's prices, and in the loss of several carloads of small oranges in Detroit because their wholesale price was too high in comparison with the retail ceiling price.

Politically, the problem of keeping the price level approximately even is complicated by the fact that the Office of Price Administration has no control over wage rates and is legally handicapped by the parity formula for fixing price ceilings for many basic farm crops. Since wage costs and prices for farm products are among the most important components which affect the general price level, it is evident that the price-control agency has been given the responsibility for keeping prices under control without adequate authority over large segments of our economic system. Moreover, the formula definitely relates the prices of agricultural products to the general price level, which, in turn, is a basis both for fixing parity prices for agriculture and for adjusting wages upward. Thus is created a vicious inflationary spiral that makes the control of prices most difficult.

The attempt to control prices has also been handicapped by specific limitations within the law which established the Office of



**Price Administration.** The authority granted does not permit it "to compel changes in the business practices, cost practices, or methods or means or aids to distribution, established in any industry, except to prevent circumvention or evasion of any regulation, order, price, schedule, or requirement under the act." This statement is interpreted as forbidding the agency to compel grade labeling on consumer goods, and adds to the difficulty of preventing concealed price increases through manipulating the quality of merchandise sold to the public. The same provision in the law also prevents any exercise of legal control over most channels of distribution. Some channels are difficult to supervise and can be used by unscrupulous businessmen to draw off merchandise into the black market.

From the social angle consideration should be given to black-market operations and the effect price ceilings have had on production. The debacle in the marketing of gasoline at the present time is evidence of how the control of prices breaks down when a serious shortage occurs in a common necessity. Similar black markets may be expected for other common items whenever a real scarcity of an item is combined with an intense consumer demand. As the war continues and scarcities become more acute, more stringent methods of control must be devised. At present the law and social pressure limit the use of the most effective methods of controlling black-market operations. It may be expected, therefore, that such operations will become considerably worse than they now are before society will permit a governmental agency to make radical changes in the economic system for the purpose of minimizing them.

In view of all the economic, political, and social difficulties that have been encountered it is surprising that the increase in the general price level has been held between January 15, 1941, and December 15, 1943, to the 23.2 per cent calculated by the United States Bureau of Labor or even to the 40-odd per cent announced by organized labor. On the basis of the governmental index our increase during the past three years is less than the increase in wages or in farm-commodity prices; is less than the increase for the comparable period in the first world war; and is slightly less than the general wholesale increases in Australia, Canada, and the United Kingdom.

The economic, political, and social handicaps under which the Office of Price Administration operates do not mean that the vast majority of people do not favor price control, at least in principle.

The need for it was seen almost a year before the United States entered the war. In recognition of this need the agency was established by executive order in February, 1941, with very little real authority over prices. Then began a bluff-and-bluster period of price control under the administration of Leon Henderson. The period ended with the passage of the Emergency Price Control Act in January, 1942. This act, however, did not objectively change the effectiveness of the agency until the issuance of the General Maximum Price Regulation, which received its legal status under the act, was put into effect in April, 1942.

From January, 1941, to May, 1942, the index of the cost of living increased 15.1 per cent, or approximately 1.0 per cent per month. During this same period the composite farm-price index of the United States Department of Agriculture rose 46.1 per cent, and the gross hourly wage rate in manufacturing industries, as reported by the Department of Labor, increased 20.6 per cent.

From May, 1942, when the General Maximum Price Regulation went into effect, until December, 1943, the index of the cost of living of the Department of Labor increased only 8.1 per cent, or less than 0.5 per cent per month. For the same period the farm-price index rose an additional 43.3 per cent over January, 1941, and average gross hourly earnings increased another 24.4 per cent over January, 1941.

An analysis of the foregoing statistics indicates that the Emergency Price Control Act slowed down substantially the rise in the index of the cost of living — less than one third of the total increase has occurred since the legislation went into effect — and that the indexes for farm commodities and hourly industrial wage rates have increased during the second period far more than the index of the cost of living. It may be concluded, therefore, that the Office of Price Administration has done excellent work in limiting the price increases in the cost of living. Our enthusiasm for its performance is enhanced by the existence of an "inflationary gap" of many billions during the period the act has been in effect and is lessened by its use of subsidies at an annual rate of \$1,140,000,000.<sup>1</sup> The net result of these forces upon the agency's effort to minimize price increases cannot be calculated with any degree of confidence. Price

<sup>1</sup> Haskell, A. Porter, "Price Control and Methods," *Survey of Current Business*, Vol. 23, No. 12, United States Department of Commerce, Washington, D.C.

freezing has eliminated the effect of the inflationary gap except as it exerts an influence on the black market and on public agitation to raise ceiling prices. In many instances subsidies have prevented increases in such prices in spite of increases in wages and in the price of farm commodities. Subsidies have kept marginal industrial units in full operation without revising price ceilings for entire industries. It may be said, therefore, that subsidies have been a most powerful weapon in maintaining low ceiling prices; consequently, they have been the point at which the Office of Price Administration has received its most vicious political attacks from those who are interested in forcing higher prices upon the public. Without doubt the power to freeze prices and to use subsidies has been the internal reason for its success in minimizing the rise in the cost of living.

Externally the reasons for a high degree of success in the control of prices are found in the social and economic environment. The vast majority of citizens want the policy of price control to operate successfully, and thousands of unpaid volunteers give unselfishly of their time to make it a success. The entire venture has been aided by economic conditions which are favorable to maintaining relatively stable prices in spite of the war. The more important of these conditions are as follows:

1. The United States entered the war with heavy inventories ranging from raw materials to finished goods in the hands of the consumers. These surpluses, together with the additional production since the war began, have represented for most items of merchandise too large a supply to permit runaway prices even if no control over prices existed. The surpluses in usable form for the consumer have dwindled rapidly and will not give so much aid in controlling prices in the future as they have done in the past.

2. The shortages which now exist are mostly in the finished products and not in raw materials that might easily be diverted for the production of consumer goods. The bottlenecks are manpower and factory capacity now used for the production of matériel. At any time the government, through the release of a relatively small amount of manpower and factory capacity, could flood the market with any specific item which threatens to sell at inflationary prices. This threat dampens the ardor of most speculators to hoard vast quantities of merchandise with the expectation of selling it for prices far above present ceilings. For example, the present scarcity of

liquor, with the consequent high prices in the black market, represents a situation in which speculators can operate only in the immediate market. Importations and the diversion of only a small part of our present capacity to the production of liquor would ruin the market for all but the choicer brands. Thus our potential productive capacity is a second item favorable to maintaining relatively stable prices in spite of the war.

3. No matter what our attitude toward big businesses, their existence at the present juncture has been a great help to the Office of Price Administration in enforcing its ceiling prices. Relatively to size big businesses are far easier to police than small businesses. They keep more and better records, may be expected to file more intelligent reports, and are policed more vigilantly by the public. In the field of distribution proportionately far more violations of ceiling prices are found among small retailers than among the large mail-order houses, department stores, and grocery chains. In the distribution of food the large grocery chains, through careful compliance, have done much to acquaint the public with true ceiling prices, and thus have aided in making the ceilings effective. To a somewhat lesser degree the same statement is applicable to the chain stores in other fields and to the larger department stores. Unfortunately, from the standpoint of enforcement the unstandardized nature of such commodities as yard goods and wearing apparel makes unintentional violations of ceilings more likely, and intentional violations more difficult to prove than violations in the sale of such lines as groceries, in which standard grades are rather well established.

4. Prices have been kept near prewar levels by the nature of overhead costs and by the exigencies of the war. These have enabled business to pay wage increases which are far greater than the increase in commodity prices. Full production, instead of the lower production rate of peacetime, has, in many instances, substantially reduced the overhead cost per unit of output. In many businesses this reduction has been sufficient to cover the increased wage cost and to provide the largest net profit before the deduction of income taxes since 1920.

The exigencies of the war have supplied numerous reductions in the cost of operation which businesses could not secure under peacetime conditions. Besides full production with its lower cost per unit

of output, costs have been reduced through the elimination of many expensive services that were commonly given in the prewar years.

The arbitrary return of merchandise by purchasers plagued vendors for years prior to the war. The scarcity and the threatened scarcity of merchandise under war conditions have caused vendees to keep merchandise, even if it is not up to specification, and also have led vendors to refuse the return privilege to customers for merchandise which has been legally sold.

Delivery services have been consolidated, reduced, and, in some instances, eliminated entirely. Wrapping materials for merchandise have been greatly cheapened. Extra charges are now made for special packaging, and free unessential services to customers have been largely curtailed. Financial prosperity has reduced the amount of loss on credit transactions. In the retail field a Federal regulation freezing customers' accounts that are over thirty days past due and an increased willingness of customers to pay cash for their purchases have resulted in savings by decreasing credit as well as by increasing cash transactions in both number and amount.

Further reduction in expenses has been brought about through inability to hire personnel for the performance of important but temporarily nonessential activities and also to replace equipment that has become obsolete through changes in fashion, such as counters, tables, and display materials.

Besides increasing their net profit through the decreases in expenses so far considered, many businesses have raised their dollar margin of profit by three other methods without violating ceiling prices:

1. Discontinuance of extra discounts which certain customers enjoyed in the plentiful prewar period. Quantity discounts, extra datings, and many other schemes which reduced the net price were eliminated before the General Maximum Price Regulation went into effect.

2. A large decrease in the price reductions which were formerly taken for end-of-the-season and other special sales. In wartime such reductions are not necessary to clear stocks and, consequently, ceiling prices give a margin of gross profit greater than in prewar years.

3. Production and handling of only the necessary minimum of low-margin merchandise. Demand for many items has been such

that all the higher-margin merchandise that could be produced could be sold.

The various causes of reduced expense and increased margin which have been considered explain why, with merchandise under price control, businesses have made an outstanding profit record in spite of the fact that labor costs and the costs of all raw materials coming from agriculture have increased relatively far more than wholesale and retail prices. In looking ahead it may be noted that most of these conditions which have permitted business to absorb the increases in wages and raw materials during the past three years will not give the same protection that they formerly did. That the present administration realizes this situation is indicated by its strenuous efforts to prevent further price increases.

In only a few instances has a low price ceiling been responsible for a breakdown in the production of commodities which have been needed for the civilian population or for the war effort. Such mistakes have, in general, been corrected with no great loss in production and no great hardship to consumers. By and large, it has interfered but little with securing the maximum production of merchandise necessary for the well-being of the public.

The rather loose enforcement policies used by the Office of Price Administration have been successful primarily because as a rule business has accepted the principle of price freezing for the duration of the war. This acceptance has been brought about by the patriotism and intelligence of businessmen and the economic conditions, already discussed, which enabled them to operate profitably under price ceilings.

Businessmen are far from unanimous in favoring bureaucratic control of prices. The voice of agriculture opposes it for farm products and also subsidies which are given in lieu of price increases. Real-estate operators find the control of rental prices effective though onerous. Most businessmen, however, accept price control as a necessity in our war economy. They grumble at the extra burden it has placed upon their organizations, but realize that some extra work is required if price control is to be effective. In many industries the business managers believe they can suggest methods of controlling prices better than those now in use. But to them price control at the present time is of minor importance in comparison with the problems arising from other sources. Among these are the military

draft, wage freezings, the forty-eight-hour week, the demands of labor unions, the limitations on materials set by the War Production Board, the uncertainty of deliveries from vendors, renegotiation of government contracts, and the excess-profits tax, all of which make relatively unimportant price ceilings which are sufficiently high to permit profitable operation.

The fact that close to maximum production of the most-needed products has been achieved under prices controlled by the Office of Price Administration indicates that in this field it has been highly successful, provided the price increases and the subsidies which have been given are not considered excessive.

Political complications confuse any evaluation of the increase in prices over the past three years. Much of the change obviously has been caused by higher prices for agricultural products and for labor, over which the Office of Price Administration exercises little or no control. The poorest record now being made by the agency is in coping with black-market operations. Here the blame does not rest entirely upon it, both because there are limitations in the law under which it operates and because the public is not yet aroused to the dangers of the black market. Perhaps the fact that the general public shortly will have only three gallons of gasoline a week because many are riding on black-market gasoline may change the public attitude sufficiently to permit the stronger enforcement measures which would minimize black-market transactions.

For the future the Office of Price Administration may be expected to fight a rearguard action against rising prices. It will yield to higher prices so far as such prices are necessary to maintain full production. How rapidly prices rise will depend on government policies over which the Office of Price Administration has no control and, for the next year at least, upon what changes the present Congress makes in the Emergency Price Control Act.

UNIVERSITY OF MICHIGAN  
(March, 1944)

# LANGUAGE AND LITERATURE





## THE RECEPTION OF DAUDET'S *SAPHO* IN THE UNITED STATES

ALPHONSE R. FAVREAU

THE tenor of critical opinion of Alphonse Daudet has fluctuated greatly since his first works were introduced to the American public. Though few of his longer novels are read today, mention of his name instantly recalls to mind such favorites of the classroom as *Tartarin de Tarascon*, *Le Petit Chose*, and *Lettres de mon moulin*. Yet, surprisingly enough, these and his other early works remained unnoticed for more than a decade before they were read and appreciated in this country. In France and in Britain, to be sure, these classics were equally slow in attaining recognition; therefore, we could hardly expect to find his tales of remote Provence achieving immediate success on this side of the Atlantic.

A thorough examination of American reviews from 1875 to 1900 reveals three rather clearly defined periods in the acceptance of Daudet's works. The first, from 1876 to 1878, shows the firm establishment of Daudet in the United States as a talented novelist, worthy of bearing the closest watching. From an unknown writer he rapidly assumed a position of great importance. His first realistic novel, entitled *Sidonie* in the American translation (*Fromont jeune et Risler aîné* in French) awakened America to his brilliant talents; the two novels that followed, *Jack* and *The Nabob*, definitely fixed his reputation here. In two short years, then, Daudet became recognized in this country as an author of considerable consequence.

During the succeeding six years, the second period, Daudet quickly gained preëminence with *Kings in Exile*, *Numa Roumestan* — his masterpiece — and *The Evangelist*. Several qualities in his writing set him apart from other French novelists of the time. His Dickens-like strain was hailed by Americans as one of the chief delights of his style. For in this simplicity and purity of sympathy his imagination was of a most graceful cast. "He had in no way bound himself over by the same rigid contract to call a spade some-

thing worse than a spade,"<sup>1</sup> as had the Zolas and the Goncourts. For years Daudet remained the only French novelist widely enjoyed in the United States because his imagination softened the impact of brutal reality so prevalent among his contemporaries. Above all, his gift of humor linked him to his Anglo-Saxon readers.

His humor is far greater than that of any modern French novelist, and is the real English humor of character — the humor that delights in sympathetic reproduction of all types, bad and good, not from an ideal or even a strictly real point of view, but from that point which humor alone supplies.<sup>2</sup>

His great skill in character delineation, especially of such contemporary personalities as the Duke of Morny, in *The Nabob*, appealed strongly to American critics. The cleverness with which he took a plot from contemporary France and produced almost photographic pictures of the Second Empire made Americans eager to read each succeeding work as soon as it appeared.

Though at this time he was publishing a novel nearly every year, they did not come forth fast enough to please his vast American public. People therefore turned to his earlier works and found in them greater pleasure than they had experienced even in his longer novels. Henry James, writing in the *Atlantic Monthly*, confessed to an extreme fondness for Daudet. It was not his longest works, however, that he liked best, but *Lettres de mon moulin*, *Contes du Lundi*, *Le Petit Chose*, and the exquisitely amusing *Tartarin de Tarascon*. These contained, in his opinion, the cream of the author's delicate and indescribable talent. In these sketches lay Daudet's perfection.<sup>3</sup> "At present," James again wrote in 1883, "we have no one, either in England or in America, to oppose to Alphonse Daudet . . . . He is at the head of his profession, he is a novelist to his fingertips, he belongs to our modern class of trained men of letters."<sup>4</sup>

The critic of the *Literary World* summed up Daudet's position in 1881 in words of highest commendation.

Every new production of M. Alphonse Daudet's pen is a delightful surprise. No page of contemporary French literature is more fascinating than that which records his triumphs. His progress as an artist has been even and strong; he has felt his way carefully; the dainty studies of country life with which he

<sup>1</sup> "Literature of the Day 'Le Nabab,'" *Lippincott's Monthly Magazine*, 21 (1878): 645-646.

<sup>2</sup> "Le Nabab," *The North American Review*, 127 (1878): 173-176.

<sup>3</sup> James, H., "Alphonse Daudet," *The Atlantic Monthly*, 49 (1882): 846-851.

<sup>4</sup> James, H., "Alphonse Daudet," *The Century*, 4 (1883): 498-509.

charmed the readers of less than twenty years ago have gradually given place to more elaborate works, until the author of *Numa Roumestan* takes his place perhaps at the head of all living writers of fiction. Not since Balzac has France seen M. Daudet's equal. His strength lies in the combination of what have long been regarded as conflicting or incompatible endowments. To a method that is realistic in the extreme he adds the most exquisite faculties of expression; the subtle analysis which forms the groundwork of his skill is allied with the poetry and pathos of a refined imagination. In the study of human passion his insight far surpasses that of M. Zola; . . . he has painted rural life with a delicacy worthy of George Sand; his portrayal of character is as pitiless as that of Flaubert; lastly, his fine quality of humor has more than once called forth favorable comparison with Dickens. It is easy to see how such a writer may be claimed by M. Zola as a follower under the banner of the naturalists, and at the same time win the applause of the opposing school. M. Daudet has met the *soi-disant* disciples of realism on their own ground, and shown them that pathological studies of human nature are not enough to constitute the permanent in literary art.<sup>5</sup>

Thus in 1884 we find Daudet at the height of his career. Magazines eagerly printed items announcing his forthcoming novel, *Sapho*. And with *Sapho* began very abruptly his third period — a marked decline in enthusiasm for his realistic novels, and the gradual emergence of his tales and imaginative works as classics. Of this period I wish to discuss at some length only one phase — the effect that this novel and its subsequent play produced on the American public.

Theodore Child announced from Paris in the spring of 1884 that *Sapho* would be published simultaneously in French, German, Italian, and English.<sup>6</sup> The firm of Funk and Wagnalls, then of New York, had offered Daudet a large sum for the advance sheets of the work so that they might publish it on the day set. It was the first time a French novelist was to receive payment from an American firm for translation rights of his work.<sup>7</sup> The offer was accepted, and the sheets were sent.

Now an amusing incident took place. For when the publishers received the sheets and read their contents, they decided they could not issue the book and cabled the author: "*Sapho* will not do." This dispatch completely baffled Daudet, quite unaware of America's outlook on morals at the time. He consulted with several of his friends in regard to the meaning of such a message. An unusually acute friend pointed out to him that "*Sapho*" was spelled with two p's in English, whereas, he said, in French it followed the Greek

<sup>5</sup> "Numa Roumestan," *The Literary World*, 12 (1881): 411.

<sup>6</sup> Child, Th[eodore], "Parisian Literary Notes," *American*, 8 (1884): 105.

<sup>7</sup> *Ibid.*, p. 105.

spelling of one *p*. This must have relieved the novelist, for he cabled back to the publishers: "Spell it with two *p*'s."<sup>8</sup> Needless to say, the publishers were more astonished at Daudet's reply than he had been at their cable.

Notwithstanding Daudet's helpful suggestion, Funk and Wagnalls refused to publish the novel, because, they said, its character was found to be too much at variance with that of their other publications. To clear themselves they issued the following statement on July 9 of that year:

M. Daudet, we hear, has been pleased to expend no little satire and irony on the United States because a publisher in that benighted land called his novel of *Sappho* "objectionable" and declined to bring it out. M. Daudet has a singular idea of propriety if he thinks that *Sappho* is not objectionable. Let him hie him forthwith to fresh woods and pastures new, if he wishes to maintain his reputation.

We deeply regret to have brought upon the United States M. Daudet's wrath, but there cannot be two opinions in this country or in England of the character of the book mentioned. We have seldom seen a book more objectionable. In view of M. Daudet's criticism it is but fair to us and to the United States (for it seems that the reputation of the entire country is involved) to say that when we found that the book was one upon which we could not place our imprint, we so notified M. Daudet, and promptly paid him in full what he claimed as "indemnity" for our refusal to publish, although we did not deem ourselves, in view of the character of the book, either legally or morally bound to pay him anything.<sup>9</sup>

America, nevertheless, was to have its chance to read the much-discussed novel. For a sensational New York firm had a cheap paper edition of the book on the market almost on the morning after the next French packet arrived. A copy of the original was torn into three parts and divided among as many men, each of whom proceeded, with the assistance of typewriters and stenographers, to translate his "take." The feat was accomplished by sunrise, and in an incredibly short time the printers and binders had the edition ready.<sup>10</sup>

Daudet, indeed, could have chosen no better work with which to estrange himself from his American public. The press immediately started a crusade against the book. American morals were simply not ready to accept its controversial theme. The story of a five

<sup>8</sup> "The Lounger," *The Critic*, 21 (1897): 8.

<sup>9</sup> "A Defense of the United States against M. Daudet," *The Publishers' Weekly*, 26 (1884): 133.

<sup>10</sup> "Daudet's Reminiscences," *The Bookbuyer*, 5 (1888): 276-277.

years' liaison of an honest young man of good family, who falls under the fascination of a courtesan, was more than America could stomach, "especially when that courtesan had successfully been the mistress of half the artists and literary men in Paris."<sup>11</sup>

M. Daudet's hideous *Sapho* is an illustration of further depths to which a writer may descend when he has ceased to allow his imagination that ennobling idealizing influence upon his work, which of right, belongs to it . . . . In *Sapho* we see M. Daudet completely delivered up to one of the most revolting subjects upon which pen was ever employed.<sup>12</sup>

"Would America never see French fiction delivered from the thralldom of her sempiternal harlot?"<sup>13</sup>

Its very title was far too suggestive for American minds, its dedication, "to my sons when they shall have reached twenty," offensive.<sup>14</sup> American reviewers were not responsible if French youths should read this work, but they definitely declined to offer it to American men of more mature years. Furthermore, "it had best not be read by the American lady of any age."<sup>15</sup>

It is obvious from these criticisms that American morals were at complete variance with the French of that day, and that Americans utterly refused to see the didactic value of the novel. Though the critics were against it, *Sapho* was widely read, nevertheless, for in the next twenty-five years at least twenty different editions were published by as many firms. A number of these editions were cheap paper-covered copies, hurriedly printed up and sold for twenty-five and fifty cents. One is of particular interest. The Hotel Taft in New York placed in its rooms copies of its privately published edition bearing the imprint "Tarry at the Taft." Considering the number of apartments Jean Gaussin and Fanny Legrand frequented in the book, it must have seemed a specially apt hotel advertisement.

It took sixteen long years for *Sapho* to find a defender in this country. Only in 1900, three years after Daudet's death, did H. T. Parker write in the *Bookman* that "*Sapho* was one of the world's great books. It is a terrible, truthful, pitiless picture, in the first place, of a woman who has frankly and freely abandoned herself to a life of lawless love, and who is finding herself near the time when

<sup>11</sup> "Parisian Literary and Art Notes," *American*, 8 (1884): 184-185.

<sup>12</sup> "Recent Fiction in English and French," *The Critic*, 4 (1884): 114-118.

<sup>13</sup> "Parisian Literary and Art Notes," *American*, 8 (1884): 184-185.

<sup>14</sup> *Ibid.*

<sup>15</sup> "Recent Novels," *The Nation*, 39 (1884): 19.

her fascinations are fading and when amid all her physical charm there is beginning to creep in a premonition of decay." This critic believed the novel was "written by a great artist without prudery or pruriency, and that a mature reader would find no indecency."<sup>16</sup> Such is the opinion of the reader of today. For no one who knows conditions of Paris during the Second Empire and is equally well acquainted with Daudet's affection for the youth of his land can believe that his motives were other than sincere and instructive.

As with most of Daudet's novels, *Sapho*, too, was turned into a play. Gabrielle Réjane portrayed it in New York in 1895 — in French, of course — and ten years later Sarah Bernhardt did likewise. It was to be expected that it would find an American adapter, who, in this case, was the well-known playwright, Clyde Fitch. The celebrated English actress, Olga Nethersole, brought her company here in the fall of 1899 and, after a tour of several months, the play opened on February 5, 1900, at the Wallack Theater in New York. From the very beginning it was obvious that it would receive much notoriety. In the theatrical Sunday supplement of the *New York Herald*, previous to its showing the editor awakened his readers to the quality of the play, if, indeed, they needed any instruction.

. . . [Sapho] is a story of downright unblushing immorality in the play as much as it was in the book. Let's have no nonsense about it from the very outset, and in speaking of it, let's not pretend that it is not so candid as reported. It is every whit as frank as the book, and being acted instead of read, it seems more so.<sup>17</sup>

The critic who reported the play wrote in the same vein:

. . . [It is] unreasonable to expect that Daudet's masterly, yet to many readers, repulsive, novel, *Sapho*, could be made into a clean, wholesome and delicate drama. And no one expected it.

However, no one who went . . . to see Daudet acted was looking for the dramatization of the *Pilgrim's Progress*. Presumably he or she understood perfectly what they were looking for and were not surprised when it came along. The play presents all the salient features of the book, it is not squeamish about calling a spade a spade, and not only that but naming the whole thirteen cards of the suit!

The scene of *Sapho* reading in *toto* the confidential letters of her former lovers, certainly passed the limits of discretion and propriety. But otherwise, there was nothing in the play which the rather *blasé* theatregoing public, familiar with the *risqué* plays that have been given here in the last few years, could cry out at. Of course it told the story of *Sapho's* and *Jean's* love life with perfect

<sup>16</sup> P[arker], H. T., "Concerning *Sapho*," *The Bookman*, 11 (1900): 158-159.

<sup>17</sup> *The New York Herald*, January 21, 1900.

freedom, but you knew that it was to be told when you went to Wallack's. So what's the use of raising a rumpus about that?"<sup>18</sup>

Thanks to Miss Nethersole's excellent acting and production, *Sapho* immediately became a *succès de scandale*, and seats were selling a month in advance. The actress gave frequent interviews with newspaper reporters and tried to defend her play as well as her good name. She said she was accustomed to sharp criticism after her ten weeks' tour of the country. In one western city a clergyman had accused her of "spreading moral miasma."<sup>19</sup> But to her, *Sapho* was moral in that it taught with overwhelming force a profound moral lesson. Its theme was the regeneration of a woman's soul through love. "No play could have a greater one than that."<sup>20</sup>

The play ran for a month and a day, when it was closed on March 6 by order of the police as a public nuisance. Miss Nethersole, her leading man, and two managers were arrested, but appealed the case. The indictment as taken from the *Herald* reads as follows:

The indictment charges the four defendants with the crime of unlawfully committing and maintaining a public nuisance *Sapho*, . . . in a lewd, indecent, obscene, filthy, scandalous, lascivious and disgusting manner, mak[ing] divers lewd, indecent, obscene, filthy, scandalous, lascivious postures and attitudes, and repeat[ing] and utter[ing] indecent, obscene, filthy, scandalous, lascivious and disgusting words and conversations, all of which said acts, words and conversations then and there grievously offended public decency, and which said motions, postures, attitudes, words and conversations were and are so filthy, nasty, corruptingly obscene and disgusting, that a more particular description thereof is not fit to be set down in these allegations or spread upon the records of this honorable court.<sup>21</sup>

To all this Miss Nethersole's attorney remarked: "We are perfectly satisfied."

Oddly enough, he was correct, for after the trial began on April 6, it lasted just two days, and the jury quickly found a verdict that the play was not an offense to public decency. *Sapho* started up again the next night. During the staircase scene at the end of the first act storms of cheers and cries of "Bravo" came from all parts of the house. The audience seemed especially anxious to stamp with its approval the scene that had been most severely criticized. The applause lasted for five long minutes and "was like nothing so much as a Presidential convention stampede."<sup>22</sup> The play ran triumphantly

<sup>18</sup> *Ibid.*, February 6, 1900.

<sup>20</sup> *Ibid.*, February 11, 1900.

<sup>22</sup> *Ibid.*, April 8, 1900.

<sup>19</sup> *Ibid.*, February 7, 1900.

<sup>21</sup> *Ibid.*, March 23, 1900.



until the close of the theater season and was brought back again by Miss Nethersole the following autumn.

During the time Olga Nethersole's production was in the hands of the courts many small companies, the country over, set about to present this sensational play. By way of conclusion it may be interesting to note that we had, not far from Ann Arbor, our own *Sapho* production. In Kalamazoo on March 15 of the same year a local company "was doing it up in great shape when in the middle of the first act, the police decided that Kalamazoonian [*sic*] morals were at a danger point and the curtain was rung down. A red hot discussion was followed by two attempts to raise the curtain, frustrated by the portly chief of police, who had got up in the flies and was sitting on the roller. Though the audience stood up, and sang 'There'll be a hot time in the old town to-night' the weight of the chief of police was greater than that of the public's enthusiasm"<sup>22</sup> — the lights were lowered, money was refunded, and *Sapho* did not mount the stairs in the arms of her beloved Jean.

UNIVERSITY OF MICHIGAN

<sup>22</sup> *The New York Herald*, March 15, 1900.

## AN ANALYSIS OF PRISON JARGON

V. ERLE LEICHTY

**J**OINT GAB," the jargon of the inmates of our penal institutions, differs, as one of my informants indicates, from the language which is employed by the underworld outside. At the same time it makes use of many of the terms found in the various occupational argots of the underworld. Apparently, it cuts across most of them, but it is by no means a common denominator. Localisms which develop within each institution seem to vary not only from place to place but also with the type of inmate. Thus the joint gab of a Southern chain gang would differ considerably from that of prisoners in Sing Sing, and both would be unlike that used in Alcatraz; yet all three might have some locutions in common with the language of Chicago pickpockets or St. Louis dope peddlers.

To make anything like a definitive study of such jargons would require a lifetime. The investigator would have to become personally acquainted with informants inside and outside institutions and gain their confidence before they would give him accurate information. It would then be necessary to check and recheck the data, for few of the prisoners would have sufficient linguistic background to enable them to make the distinctions necessary for such research.

The data for this paper were gathered through correspondence with two inmates of the Illinois penitentiaries. Nothing is known of their backgrounds except that one of them had also served time at Walla Walla. Most of the material was in the form of paired expressions such as "elevator — a gun" and "to eye — to look at." Many of the terms included as prison jargon are common not only to the underworld but to the general public as well. It is possible, therefore, that the results obtained from the small sampling used for this study may prove to be entirely erroneous when a more nearly complete study of this type is made.

This article will attempt to show that such jargon appears to make use of many of the grammatical and rhetorical devices current

in ordinary English. In spite of this and although many of the terms are familiar to the layman, he would have considerable difficulty in understanding the jargon in context. Let us consider the following paragraph:

Sure I been away, making kicks over at the walls. The cuter<sup>1</sup> got me for a jug<sup>2</sup> job, and the beak<sup>3</sup> threw me a finif.<sup>4</sup> I flew a kite to my rapper, and he called off the dog,<sup>5</sup> so after I pulled a deuce and a half they slipped me a sawbuck<sup>6</sup> and a phoney<sup>7</sup> fiddle and flute, and I'm on the bricks. Now all the bottles and stoppers are wise, so I can't square-John it.<sup>8</sup> I gotta get me a heat<sup>9</sup> and a short,<sup>10</sup> but no more junk.<sup>11</sup> That's what jammed<sup>12</sup> me before. I wouldn't make a buy<sup>13</sup> off Santa Claus.

To the joint gabber this paragraph means:

Yes, I've been in Walla Walla prison, making shoes. The prosecuting attorney convicted me of a bank burglary, and the judge sentenced me to five years.

<sup>1</sup> Sometimes spelled "cutter," "kuter," "cutor." The term is included in M. H. Wesen, *Dictionary of American Slang* (New York, 1934).

<sup>2</sup> "Jug" was used as early as 1815 for "jail." Eric Partridge, *A Dictionary of Slang and Unconventional English* (New York, 1938), gives an example of the word with the meaning "bank," c. 1860.

<sup>3</sup> N. E. D. cites "beak" in its earlier form "beck" in a use dated 1573: "The Harman beck, the counstable." D. A. E. has an 1859 citation under "cop."

<sup>4</sup> Partridge, *op. cit.*, gives an example of the use of this term in England for a five-pound note c. 1835. In the United States it may mean five dollars, five years, etc., or simply five. It may be from German *fünf*.

<sup>5</sup> "To call off the dog," as has been indicated, means to stop prosecution. "The dog" or "the old dog" is a term for syphilis, and "dog" without the definite article indicates any kind of sausage.

<sup>6</sup> "Sawbuck" may mean ten, ten dollars, ten years, and so on.

<sup>7</sup> N. E. D. Supplement cites the *New York Evening Telegraph* for December 8, 1904: "This word phoney . . . implies that . . . a thing so qualified has no more substance than a telephone conversation with a supposititious friend." See also Peter Tamony, "The Origin of 'Phoney,'" *American Speech*, 12 (1937): 108.

<sup>8</sup> "Square" is the antonym of "cross." It is used to indicate a law-abiding person or anything that is legitimate. D. W. Maurer, "Argot of the Underworld Narcotic Addict," *American Speech*, 11 (1936): 120, records "square John" as prison jargon for "taxpayer."

<sup>9</sup> "Heat" is most frequently used to signify trouble or police in the outside world. "Heater" is a general term for gun; inside, it has the prosaic meaning of stove.

<sup>10</sup> I thought this term might be from "short circuit" (short-circuiting ignition is a common means of car theft), but Professor D. W. Maurer (University of Louisville) informs me that it was in use for streetcars before the days of the automobile.

<sup>11</sup> See D. W. Maurer, "Junker Lingo," *American Speech*, 8 (1933): 27-28, 33-34.

<sup>12</sup> Note that "to get in a jam" is everyday slang. Compare note 14.

<sup>13</sup> "To make a buy" is to purchase narcotics.

I sent (or smuggled out) a letter to the complaining witness, and he was willing to have me released; so after serving two and one-half years, I was given ten dollars and a cheap suit, and I'm free. All the police watch me so closely that I can't hold a job. I'm going to get a gun and a car, but no more morphine. That caused me to be arrested before. I wouldn't take it as a gift.

## GRAMMATICAL DEVICES

An examination of the paragraph of prison jargon shows that it appears to follow the normal rules of English syntax. The word order is the regular subject-verb-complement pattern. Additional examples are:

He's jam up.<sup>14</sup>  
He took it on high.  
They put him in the sweatbox.  
He copped a sneak.  
We were panning<sup>15</sup> the joint.

He took a powder.

He's not one who carries tales.  
He went away fast.  
They questioned him concerning a crime.  
He left without being noticed.  
We were talking about the prison or prison administration in derogatory terms.  
He ran out (generally leaving someone else in a bad spot).

Noun attributes are apparently used with adjectival force in the jargon, as they are in normal English. Thus "lush"<sup>16</sup> is liquor, and a "lush hound"<sup>17</sup> is a habitual drunk. A doctor may be a "pill shooter,"<sup>18</sup> a psychiatrist may be a "bug doctor" or a "nut doctor," and the detention hospital for unusual patients is frequently referred to as "bug cells." "Stir," which may be a noun for jail or prison, may become a part of a compound adjective. "Stir-simple" indicates mental stagnation due to incarceration. A first offender is "stir-shy," and one who is "stir-broke" is prison-wise. A "box"<sup>19</sup> is a safe, a "cracker box" is a cheap one. In Illinois "*Tribune time*"<sup>20</sup> is the additional time beyond the date of eligibility for

<sup>14</sup> Weseen, *op. cit.*, defines this expression by "to serve full time." Partridge, *op. cit.*, gives an older meaning, "in the pink of perfection."

<sup>15</sup> The idiom "to pan out," which seems to have been common c. 1914-18, meant simply "to talk freely." "To pan" in the derogatory sense seems to be a more recent development.

<sup>16</sup> The term has been in use since 1790. See Partridge, *op. cit.*

<sup>17</sup> "Lush cove" is the British equivalent.

<sup>18</sup> J. Redding Ware, *Passing English* (London and New York [1909]), gives the term "pill pusher" for doctor.

<sup>19</sup> "Box" has long been used to indicate a receptacle for money. Cf. Chaucer, "*Cook's Tale*," line 26: "he found his box ful bare." It seems a short step from this usage to "safe." "Box," as a prison cell, does not seem to be used in this country.

<sup>20</sup> This is, of course, a local term.

parole required by the parole board since the *Chicago Tribune* began its campaign to abolish the board. A "plow jockey"<sup>21</sup> is a person who is not too intelligent.

The normal position of the single-word modifier is before the word modified. "Hot" may mean stolen, likely to cause trouble, or under observation by an officer.<sup>22</sup> A "hot short" is a stolen car. One who associates with a racketeer, but is not in the racket, is a "square John" or "Jane." A "right guy" is an inmate who is all for the inmates and their cause. He is also referred to as a "right-O."<sup>23</sup> The "funny factory" is a detention hospital, and a "glim box"<sup>24</sup> is a homemade cigarette lighter.

The phrase modifier is placed after the element modified. When a convict is "tending bar for the captain," he is in "Siberia" or solitary confinement. "Tall weeds in a garden"<sup>25</sup> is thieves' jargon to indicate that an undesirable person is near by.

Another characteristic which joint gab seems to have in common with present-day English is the tendency to add prepositions to verbs to form idioms. If a lifer is refused parole by the board, he is said to be "racked up."<sup>26</sup> "Dummy" may mean bread, but "to dummy up" on someone is to refuse to speak to him. Prisoners refer to past enterprises by "cutting up touches,"<sup>27</sup> and talking about future escapades is "cutting up scores." "To arm" or "put the arm on" is to rob by strong-arm methods. The core meaning of words appears to be changed in such idiomatic use. "Grease"<sup>28</sup> may be

<sup>21</sup> In the seventeenth century a "plow jogger" was one who pushed a plow. Can it be that the present term is changed only by the industrial revolution? By this I do not mean to suggest that "jockey" is derived from "jogger," but, rather, that the usages may have had a similar semantic development.

<sup>22</sup> Partridge, *op. cit.*, notes the last meaning c. 1830.

<sup>23</sup> Also one who has police protection, a fence. Weseen, *op. cit.*

<sup>24</sup> The "glim box" consists of a piece of flint against which a rotating button is struck. The sparks fall into a snuff box in which rags have been placed. These were used in the old prison (Joliet), where matches were not allowed. *N. E. D.* gives "glim stick — a candle."

<sup>25</sup> This was listed as West Coast jargon. However, it does not appear to be rhyming slang.

<sup>26</sup> *N. E. D.* gives "to stretch, pull out, increase the length of . . ." These definitions are evidently based upon the old torture instrument. I prefer to think that this particular usage may have had its origin in the poolroom. The balls are generally racked up when the game is over.

<sup>27</sup> A "touch" is an act of theft, especially of pickpocketing; also a sum of money gained at once, by theft. *N. E. D.*

<sup>28</sup> "Grease" is also used for nitroglycerin. Weseen, *op. cit.*

used for butter, but "to put the joint on grease" is to discuss the institution in derogatory terms.

As in modern English, many words seem to have differing grammatical functions in different contexts. Nouns are frequently formed from idiomatic verbs. A western story is a "shootum up." A "pull-out" is a safe which can be opened by putting a "boot"<sup>29</sup> on the dial, and a "punch-out" is one that can be opened by drilling and punching. Likewise, a "prowl"<sup>30</sup> is a burglar, a "croaker" is a doctor, a "yanker" is a dentist, a "loss" is a conviction, and a "loser" is a man who has had previous convictions. He may be a "one-time loser" or a "two-time loser." In other institutions he may be a "repeater."

Verbs and participial adjectives are frequently formed from nouns. They may or may not express meanings different from those of the nouns. If a man dies of neglect in the hospital, he is said to be "black-bottled." "Weed,"<sup>31</sup> as a noun, is used for tobacco or marijuana, but as a verb it means to take only such goods as will not be immediately missed. "Clout," as a noun, is a word for lock. The verb is more idiomatic. It means to grab and run. "To be on the clout"<sup>32</sup> is to be a shoplifter. Butter, as has been noted earlier, is "grease" in prison jargon; the verb "to grease" means to pay for something which the prison rules do not allow. A prisoner cannot be "topped"<sup>33</sup> for "paper hanging" in this country, for "to top" a man is to hang him, and we do not hang people for forgery. Instead, he would have to accustom himself to "kipping" (sleeping) in a "joint kip" (prison bed). Anyone who sponges off others is said to be "mooching" or "chiseling"; and, believe it or not, even in the prisons there is "boondoggling."<sup>34</sup>

<sup>29</sup> A boot is a type of screw jack in the shape of a U, with screws at three points. By use of it the dial is literally pulled from the safe.

<sup>30</sup> "Henry Prowler" was a generalized name for thief or highwayman during the sixteenth and seventeenth centuries. Partridge, *op. cit.*

<sup>31</sup> Partridge, *op. cit.*, cites an 1811 usage — "to steal a small amount from."

<sup>32</sup> My informant defined this as "to shoplift." Professor D. W. Maurer furnished me with the meaning given in this study. He states that there are many other analogical locutions such as "to be on the heavy" (to follow the heavy rackets as a profession), and distinguishes between the verb "to clout," which means "to shoplift," and the idiom "to be out on the clout," which carries the meaning "being on a shoplifting expedition."

<sup>33</sup> "Top" has also meant "a dying speech," from "to top — to behead." Partridge, *op. cit.*

<sup>34</sup> Because of the general reaction against the competitive sale of prison-

## FIGURES OF SPEECH

Figures of speech are commonplace in any highly fluid language, and prison jargon is no exception. Examples of metonymy vary from the hackneyed "cow" for milk to "barber" for one who talks too much. Others are "typewriter" for machine gun, "twister" for key, "fix" for lawyer, and "leech" for sponger. The most poetic figure considered here is "to ride the thunderbolt," which, as may easily be guessed, means to be electrocuted. Synecdoche is represented by such expressions as "caps" for ammunition, "lip" for lawyer, "stripe" <sup>35</sup> for convict, and "green" <sup>36</sup> for money. The use of such names as "fish" for a newcomer and "wolf" for an active homosexual may represent metaphor, but until the origin of the figures is definitely established this cannot be shown. "School" for prison, "the man" for a guard or warden, and "tea" for marijuana might be regarded as examples of litotes or understatement, and even kenning may be represented in such phrases as "bug cells" for hospitals (generally psychopathic) and "harness bull" for policeman.

## OTHER RHETORICAL DEVICES

Rhyme is the basis of what one of my informants calls "West Coast thieves' jargon" or "Australian jargon." <sup>37</sup> It is interesting to observe that this type of language was first noted among the Cockneys and in the underworld of London about the time that transportation to Australia was suspended. It would appear to be

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made goods many institutions experience great difficulty in finding work for the inmates to do. As a result they are frequently kept busy on useless work.

<sup>35</sup> "One who is no longer a first offender." Partridge, *op. cit.*

<sup>36</sup> Possibly a clipping of "greenback."

<sup>37</sup> Partridge, *op. cit.*, notes that "Rhyming slang dates from ca. 1840; originated among Cockneys, where now still commonest; eschewed by the middle and upper classes, it had its apotheosis in the G. W. [World War I]." W. Matthews, *Cockney, Past and Present* (London and New York, 1938), p. 132, makes the same statement as to its origin, but notes that "Hotten, writing in 1859, says it was originally the language of the ballad sellers and apparently introduced about fifteen years before. . . . It therefore seems to have begun as a secret language. . . ." Apparently it is working from west to east in the United States. I suggest, partly because it is still known here as Australian slang, that it may have traveled to Australia with the convicts (transportation was suspended in 1839, but unquestionably such language was in existence for some time before it was recorded) and has moved from there to our West Coast. Back slang is also common among the Cockneys. See note 44.

rather difficult to use, since the meaning is dependent upon the listener's ability to supply a word that rhymes with the last term of the unit. Thus

- "Near and far" is a car. <sup>38</sup>
- "Oscar Hocks" are socks.
- "Heel and toe" means to go.
- "Bottles and stoppers" are coppers.

A closer analysis of these four phrases might lead one to conclude that they contain some additional clues to their meanings. A car is used to travel near and far, socks are worn on hocks, the heel and toe are used in walking or going, and "coppers" might reasonably be expected to be stoppers. However, no such relationship appears to be present in "lamb fry," for tie, or in "chalk farm," for arm. Mr. Matthews comments, "The best rhyming slang unites the rhyme with a social commentary, *artful dodger* (lodger) . . ." <sup>39</sup> A further complication in the use of this device is introduced by the frequent omission of the rhyming word. The name commonly given to our well-known "Bronx cheer" is an example of this development; the rhyming word "tart" has been omitted after "raspberry." <sup>40</sup> Other common examples are "elephant" (trunk), which signifies drunk, and "Abraham's" (willing), which indicates a shilling. Examples of this particular development were not identified in materials collected for this paper.

As can be seen from the illustrations already given, some of the rhyming slang is made up of pairs of words which are normally used together. Other examples are "far and wide" (hide), "ones and twos" (shoes), and "plates of meat" (feet). Proper names are also the basis of many terms. "Oscar Hocks" has already been mentioned. There are also "Lem Kegg" (yegg), "Johnny Horner" (corner), "Tommy Tucker" (sucker), and "Remington Rand" (hand). The last example is supposed to be used only locally, that is, in the northern Illinois area.

Alliteration is commonly added to rhyme, both in names such as "Dicky Dirt" (shirt) and in varying combinations such as "roses red" (bed), "lunk 'o' lead" (head), "bat and ball" (fall — that is, to be convicted), "look and linger" (finger — to stool or inform),

<sup>38</sup> It is needless to say that meaning may vary considerably in such a jargon. Partridge, *op. cit.*, translates this by "the bar" (1909).

<sup>39</sup> Matthews, *op. cit.*, p. 151.

<sup>40</sup> *Ibid.*, p. 152.



"twist and twirl" <sup>41</sup> (girl), "storm and strife" <sup>41</sup> (wife), and "fiddle and flute" (suit).

Such appellations as "jug job," "phoney fiddle and flute," and "wing ding" (a "bug" act put on by an inmate) indicate that alliteration and rhyme are not confined to West Coast jargon.

#### POSSIBLE SOURCES OF THE TERMS

To attempt to find the sources of vocabulary in any jargon is to tread upon dangerous ground. In many instances a guess such as has been made in earlier notes may be hazarded, but as in any type of popular etymology guesses are very likely to be wrong. "Yen," which is used by "dope" addicts in connection with an addiction, probably comes from a Chinese word for cigar, cigarette, or opiate. "Bluejohn," <sup>42</sup> for watered milk, was common in North Carolina as early as 1869. "Chiv" <sup>43</sup> or "shiv" was noted as thieves' cant for knife in 1673. "Poke," meaning bag or sack in Shakespeare, has long had the specialized meaning of purse in thieves' cant. "New Deal" (new rules or a new administration) and "braintruster" (an intellectual inmate) certainly need not be guessed at. "Ohday" is probably pig Latin for dough.

Many of the locutions appear to be clippings. For example, we find "hood" from hoodlum; <sup>44</sup> "hype" (an addict) from hypodermic; "bitch," a phonetic clipping, from "habitual" sentence; "benny" (overcoat) from Benjamin, the name of a tailor; "Mary" from marijuana; "legit" (anything honest) from legitimate; "cutter" from prosecutor; and "Feds" from Federal operators. The prisoners also make use of alphabetical abbreviations. They have, among others, "C" (100), "c. a. pocket" (concealed-articles pocket) and "J" (Java — coffee).

"Kite" <sup>45</sup> may be borrowed from commercial slang, but this is

<sup>41</sup> These two terms seem to be used universally and always to have the same meanings.

<sup>42</sup> Cf. D. A. E., N. E. D. Supplement.

<sup>43</sup> Cf. N. E. D.

<sup>44</sup> Partridge, *op. cit.*, suggests that "hoodlum" is "probably printer's error for 'noodlum,' [which is back slang (reverse writing) for] Muldoon, the name of a leader of a San Francisco gang of street arabs." However, it is unlikely, as Professor Maurer points out in a note on this, that the underworld would be influenced by a printer's error.

<sup>45</sup> In commercial slang a "kite" is a bill of exchange or a negotiable instrument. It is often used for raising money on credit, and may represent no actual business transaction. Cf. N. E. D.

doubtful, since the two concepts seem to have nothing in common. "Sawbuck" may be tied up with the Latin numeral X; there is nothing, however, to indicate that it is except that both the word and the number represent ten. "Stooge" and "shill" (a confidence man's helper) are common in stage and gambling diction.

As in most other jargons, some words denoting occupations and nationalities become opprobrious. "Barber" (one who talks too much) has already been noted. A "switchman" is one who inquires into other people's business. "Dutch," which is frequently connected with undesirable traits or actions, appears in the term "Dutch act," to commit suicide.

The verb "to gaffle" may be an adaptation of the nineteenth-century verb "to gaff,"<sup>46</sup> which also meant to gamble. "To case"<sup>47</sup> (to watch) has probably been borrowed from *faro*. "To keep cases in a *faro* game" is to note the cards as they come from the dealing box. "Clip" (to steal from) may possibly have developed from the old occupation of coin clipping.

From the meager amount of material available for this study it appears that prison jargon is employed in a manner quite similar to that of ordinary English. It seems to make use of many of the syntactical and rhetorical devices that are found in current English; it has its standard words which seem to be quite universally understood and its provincialisms which have only local usage, and it even shows the survival of a number of archaisms. It is perhaps well to repeat that these conclusions can be no more than tentative since they are based upon a small amount of material.

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<sup>46</sup> Cf. *N. E. D.*; Partridge, *op. cit.*, s.v. "gaff."

<sup>47</sup> Cf. *N. E. D. Supplement*; *D. A. E.*; Partridge; Wescen.

# A LIST OF WORDS AND EXPRESSIONS USED IN PRISON JARGON

(A few of these words appear in the text also.)

- bang or bing**, a quantity of drugs to be administered at one time.
- bank**, solitary. Probably from a bank of cells.
- beat**, to steal from.
- beat the man**, to deceive an official in a manner that will result in advantage to the prisoner.
- beef**, a criminal complaint.
- below**, Menard, peculiar to the Illinois penal system. Menard County, in which a penitentiary is located, is south of Joliet; hence "below."
- bird's eye**, a light dose of drugs.
- bit**, a sentence.
- blanks**, aspirin tablets. Possibly because aspirin may be void of result for one addicted to narcotics.
- blocks**, watches.
- blow your top**, to lose your temper.
- bonny fair**, hair.
- book**, a maximum sentence.
- booster**, a shoplifter.
- buck**, a Catholic chaplain.
- bug**, any inmate with eccentricities, an inmate who has been confined in the detention hospital.
- bull**, an officer.
- bum rap**, a conviction when one is innocent.
- burn**, to be electrocuted.
- can, clink, cooler**, a jail, a prison.
- cash**, legal tender. Money is not allowed in most prisons.
- cheater**, glasses or a mirror used to watch the keeper and thus avoid arrest tickets.
- chopper**, a machine gun.
- chuck**, food.
- chuck up**, to eat.
- clowns**, the police.
- clink**, *see can*.
- connection**, a source of supply, especially for narcotics.
- cooler**, *see can*.
- cream puff**, one who is not in condition to withstand rough handling.
- darby kicks**, a story that is not true.
- deck**, one dose of drugs.
- dingbat**, a mental defective.
- do an Arthur Duffy**, to run out, especially if so doing leaves another in a bad situation.
- dog eye**, a threatening look. (See note 5.)
- doing it all**, a life sentence.
- doorshakers**, merchant patrol or special police.
- dope**, a form of mental defective.
- double saw**, twenty (XX). (See note 6.)
- ducat**, a call ticket to the various departments. *See on the mope*.
- duck**, a girl friend or sweetheart in a women's prison.
- dukie**, a small lunch.
- elevator**, a gun.
- eye**, to look at.
- fall**, an arrest or a conviction.
- fence**, one who buys stolen goods.
- fields of wheat**, a street.
- finger**, a warning or information. Also to be identified or to be informed about.
- fink**, an informer.
- flatties**, detectives
- fiop**, a setback in parole, losing good time.
- frame**, a conviction when one is innocent.
- fu**, marijuana.
- gaffer**, an inmate who holds a job of some authority.
- gander**, to look at, to stare.
- gapper**, a mirror.
- geezer**, a drink of whisky.
- gimp**, one who limps.
- gimpster**, a pimp, a homosexual in prison.
- glim**, to look at.
- gun**, to look at, to stare.

**guniff**, a thief.  
**gungel**, a homosexual passive.  
**habit**, an addiction. *See* kicking a habit.  
**heist**, a robber.  
**here and there**, a pair (as a pair of policemen).  
**hit a stir**, to go to jail.  
**hole, the**, solitary.  
**hook**, a knife or a razor.  
**hustler**, anyone making an illegal living.  
**I suppose**, nose.  
**ice**, gems.  
**inside**, the old penitentiary at Joliet (peculiar to Illinois).  
**it would seem**, gleam (as a gem does).  
**jibe**, to evade work.  
**jocker**, a homosexual active.  
**johns**, the police.  
**jolt**, a sentence.  
**Judge Colt**, a gun.  
**jump into the icebox**, to sever relations.  
**keister**, a satchel.  
**kick back**, a letter that did not pass censorship.  
**kicking a habit**, breaking up an addiction.  
**kicks**, shoes.  
**Lake Eries**, ears. *See* on the Erie.  
**lam(m)**, to run out, to escape.  
**lamp**, to look.  
**leather**, a purse.  
**make**, to steal from, to be identified.  
**make a stash**, to hide away contraband.  
**mark**, a victim.  
**meathead**, a fool.  
**mince pies**, eyes.  
**moll**, a gunman's sweetheart.  
**moniker**, the distinctive name by which one is known.  
**mope**, unauthorized wandering. *See* on the mope.  
**mope**, to escape, to die.  
**mouthpiece**, a lawyer.  
**mud**, opium.  
**muggles**, marijuana.  
**muscle**, to force one's way into another's business.  
**nigger steak**, liver.  
**not rapping**, not talking to another inmate.

**office, the**, a warning or information giving some sign or indication.  
**oh by heck**, neck.  
**on the Erie**, someone is listening to the conversation.  
**on the mope**, wandering around the prison without a pass.  
**on the sneeze**, purse snatching.  
**pad**, a mattress, one's home, the place where one lives.  
**paddy**, a padlock.  
**pansy**, a homosexual passive.  
**pass**, to have an infraction of the rules overlooked by an officer.  
**peddle**, to sell state goods.  
**peddler**, one who sells state goods, a source of narcotic supply.  
**penitentiary agents**, public defenders.  
**penny**, a panhandler.  
**persuader**, a gun.  
**pete**, a safe.  
**pick**, any device for opening a lock.  
**pinch**, a report by an officer.  
**pine coat**, a coffin.  
**pipe**, to look quickly.  
**pogy**, a hospital.  
**pop**, one dose (drugs).  
**punk**, a homosexual passive.  
**pushing or showing queer**, passing counterfeit money.  
**queen**, a quean.  
**queer**, counterfeit money.  
**rap**, an accusation, an offense, a criminal complaint.  
**rap**, to speak to. Possibly from tapping on cell walls. *See* not rapping.  
**rapper**, a witness who testifies against the accused.  
**rat**, an informer, one who betrays a confidence.  
**rattler**, a train.  
**reefer**, a cigarette containing marijuana.  
**rib**, to tease.  
**ride**, a sentence.  
**roach**, a judge.  
**rocks**, gems.  
**rod**, a gun.  
**route**, a guard who will make contacts for the prisoner on the outside.  
**sand**, sugar.  
**scandal sheet**, a forbidden newspaper.

- scoff**, to eat.  
**score**, the profit from a crime, the object to be obtained.  
**screen**, limited-privilege cells other than solitary.  
**screw**, a turnkey or a guard.  
**set**, given time by the parole board.  
**setting sun**, the, a gun.  
**settled**, consideration for parole refused.  
**shake**, a thorough search by an officer.  
**shakedown**, a thorough search of a cell house.  
**shot**, a self-important inmate.  
**shyster**, a lawyer.  
**skin tight**, ready-rolled cigarettes.  
**sky pilot**, a religious head.  
**slough**, to arrest, to lock up.  
**slugs**, ammunition.  
**slum**, stew, stolen merchandise.  
**smoker**, an addict.  
**snatch**, to kidnap.  
**sneezed**, arrested.  
**sneezzer**, a purse snatcher. *See* on the sneeze.  
**snifter**, an addict.  
**snort**, one who cannot be trusted to divide the gain fairly.  
**snow**, cocaine.  
**speed balls**, a mixture of morphine and cocaine.  
**squeal**, to inform on.  
**stash**, a place where contraband is hidden.  
**stick**, a match.  
**stiff**, an unauthorized note.  
**stretch**, a sentence.  
**stretcher**, one who has only a short sentence to serve.  
**strides**, pants.  
**sugar**, money.  
**swing**, to hang.  
**tag**, a report by an officer.  
**thing**, a gun.  
**ticker**, heart.  
**ticket**, a report by an officer; a letter from the parole board stating the time to be served.  
**Tommy**, a Thompson submachine gun.  
**topper**, a hat.  
**touch**, a confidence game, a victim.  
**user**, an addict.  
**white stuff**, morphine, heroin, or cocaine.  
**worm**, a sucker, victim.  
**yacht and sloop**, "soup" (nitroglycerin).  
**yegg**, a traveling safecracker.

## THE SHARES OF MIDDLETON AND DEKKER IN A COLLABORATED PLAY

GEORGE R. PRICE

ALMOST all critics of the work of Middleton and Dekker have felt called upon to make some comment upon the nature of their collaboration in two plays of acknowledged merit, Part I of *The Honest Whore* and *The Roaring Girl*. Aside from pointing out a few clues to authorship, however, no one seems to have undertaken an organization of the facts that are determinable and pertinent. To do so for *The Roaring Girl* is the object of this paper. The effort can be justified only if it demonstrates that application of a battery of tests convincingly distinguishes the shares of the collaborators. I believe the present investigation also demonstrates that verse tests, if of several kinds and based on careful study, are a reliable instrument deserving wider use.

I shall first give the few external data which bear upon the collaboration, and then pass to an analysis of Middleton's and Dekker's styles and methods, an examination of the play in the light of several tests, an estimate of the shares of the dramatists in the composition, and a speculation concerning the method of composition.

### I

From about 1602 to 1605 Middleton was writing his early comedies of manners, in particular, *The Phoenix* (1602), *The Family of Love* (1602), *A Mad World My Masters* (written about 1604 and revised later), and *Michaelmas Term* (about 1604).<sup>1</sup> From this list, even without considering earlier work, we may assume that by 1604 he was an adept dramatist and a master of the peculiar technique displayed in his "London comedies." Dekker was an even more experienced playwright; he had probably begun writing for the

<sup>1</sup> Bald, R. C., "The Chronology of Middleton's Plays," *The Modern Language Review*, 32 (1937): 34.

stage about 1593 and is mentioned by both Henslowe and Meres in 1598, by Meres as among those best for tragedy.<sup>2</sup> Henslowe records that Dekker and Middleton, with Webster, Munday, Drayton, and others, collaborated on *Caesar's Fall* in 1602.<sup>3</sup> After 1604 Dekker worked with Webster upon *Northward Ho!* and *Westward Ho!*;<sup>4</sup> then for a time he seems to have concentrated on pamphleteering. Bald points out allusions in *The Belman of London* and *Lanthorne and Candlelight* to show that *The Roaring Girl* must have been written about the same time as those works, the winter of 1607-8.<sup>5</sup> Chambers, however, prefers 1604 because of legal evidence that Moll Frith actually presented herself on the Fortune stage in 1604,<sup>6</sup> fulfilling the promise of the Epilogue that she would appear in person. It is plausible to think that Middleton and Dekker teamed for the composition of at least two plays late in 1603 or early in 1604, Part I of *The Honest Whore* and *The Roaring Girl*. The title page of the latter contains the words "Written by T. Middleton and T. Dekkar" and the date 1611; the epistle "To the Comic Play-Readers" prefixed to the play is signed "Thomas Middleton."<sup>7</sup>

Such is the external evidence for collaboration and for the relative competence of the two playwrights. It is now pertinent to describe the style and methods of the two when working unaided and to settle on reliable indications of each man's hand. Such elements of their work as preferred situations or subject matter, constructive power, customary mood, diction, allusiveness, and versification may be considered.

Let us take Dekker first. As a whole, his work shows little development or variety in manner or matter. He repeats favorite dramatic situations. He lacks constructive power and a sense of form; his execution is likely to be uneven and incoherent.<sup>8</sup> In mood

<sup>2</sup> Chambers, E. K., *The Elizabethan Stage* (Oxford, 1923), III: 289; IV: 246.

<sup>3</sup> Greg, W. W. (ed.), *Henslowe's Diary* (London, 1904), Part I: 167.

<sup>4</sup> Chambers, *op. cit.*, III: 295.

<sup>5</sup> Bald, *op. cit.*, pp. 38-39.

<sup>6</sup> "Elizabethan Stage Gleanings," *The Review of English Studies*, 1 (1925): 77-78.

<sup>7</sup> *The Works of Thomas Middleton*, ed. A. H. Bullen (London, 1885), IV: 7-8.

<sup>8</sup> Succeeding references to the play are to this edition.

<sup>9</sup> Bases for these statements may be found in H. D. Sykes, *Sidelights on Elizabethan Drama* (New York, 1924), pp. 103-104; E. E. Stoll, *John Webster* (Cambridge, Mass., 1905), pp. 71-72; A. C. Swinburne, *The Complete Works, The Bonchurch Edition* (New York, 1926), XI: 324, 390; M. L. Hunt, *Thomas Dekker. A Study* (New York, 1911), pp. 202-203.

and emotion he is remarkably genial, simple, sympathetic, and tender; but at times this sentiment is commonplace and implausible.<sup>9</sup> Miss Ellis-Fermor, though she praises Dekker's clear observation and full memory of manners, says that he did not perceive the mental processes that make men different, a fact which "helps to distinguish him sharply from Middleton."<sup>10</sup> In contrast to Middleton and Jonson, Dekker, who is in sympathy with the middle and lower classes, uses satire only occasionally, aiming at affectation or sham that is accidental and superficial.<sup>11</sup>

Dekker's versification is distinguished by two qualities chiefly, abundance of rhyme and a rhythm "strongly accented and rapid," which in some passages charms by unction and sweetness, in others is rough, redundant, and "so crude as to descend to the level of doggerel."<sup>12</sup> Other characteristics of his poetical style are frequent iteration of words or phrases, a passion for dialect and foreign tongues, a trick of having his persons speak in chorus, a habit of making national comparisons,<sup>13</sup> and a fondness for friendly allusions to and imitation of Marlowe, Shakespeare, and other contemporaries.

When we turn to Middleton, we find a most versatile dramatist of great intellectual sympathy and lack of moral prejudice, an adaptable collaborator. In the satirical London comedies of manners, with their ironical intrigues, love is a plot relation without romanticism or ideal aspects, and potentially tragic situations are used for irony. The brilliant constructive power shown in Middleton's comedies has been testified to by succeeding playwrights who borrowed from him and by the critics. Considering plot requirements, his characterization is adequate; at times, memorable. But where Dekker is sympathetic or sentimental, Middleton is constantly

<sup>9</sup> See W. M. Dixon, "Chapman, Marston, Dekker," *Cambridge History of English Literature* (New York, 1910), VI: 58; E. Rhys, Introduction to *Thomas Dekker*, Mermaid Edition (New York, 1919), p. xxiv; A. H. Bullen, Introduction to *The Works of Thomas Middleton* (London, 1885), I: xxvi; Stoll, *op. cit.*, p. 52.

<sup>10</sup> Ellis-Fermor, U. M., *The Jacobean Drama. An Interpretation* (London, 1936), p. 124.

<sup>11</sup> See *Old Fortunatus*, II, 2, and *The Roaring Girl*, IV, 2, for specimens.

<sup>12</sup> See the descriptions by Stoll, *op. cit.*, pp. 52-54; F. E. Pierce, "The Collaboration of Webster and Dekker," *Yale Studies in English* (New York, 1909), 37: 100-101, 142; Rhys, *op. cit.*, p. xxii; Swinburne, *op. cit.*, XI: 389-390.

<sup>13</sup> Sykes, *op. cit.*, pp. 103-106; E. H. C. Oliphant, *Shakespeare and His Fellow Dramatists* (New York, 1929), I: 894; Hunt, *op. cit.*, pp. 23, 33-34.



satirical; in an unmoral society his buoyant rascals meet ironically moral ends.<sup>14</sup>

In style Middleton differs just as markedly from Dekker; he is effortless, fluent, but pithy. His versification is distinguished by constant use of double and triple endings more than any other writer's except Fletcher's. Scanning one thousand lines from three early comedies, I find an average of 32.7 per cent of double and 3.4 per cent of triple endings; figures which may be contrasted with Dekker's 10.8 per cent of double and 0.8 per cent of triple endings in an equal sampling from *The Shoemaker's Holiday* and Part II of *The Honest Whore*. Dekker and Middleton average the same number of weak endings, 0.4 per cent, and almost the same number of run-on lines, 18.4 and 15.9 per cent respectively. Middleton occasionally writes a trochaic line or uses anapests and, by slurring, crowds fourteen or fifteen syllables into a pentameter line. He also has a considerable percentage of short lines. He passes from verse to prose and back again frequently and without apparent reason.

Relatively to most of his contemporaries, Middleton uses a large proportion of rhyme (from 9.2 to 33.7 per cent) and a fair percentage of double-ending rhymes.<sup>15</sup> But as compared to Dekker, Middleton is sparing of rhyme; he averages only 20.1 per cent to Dekker's 59.3 per cent, one third as much. Middleton uses rhyme irregularly.

The peculiarities of Middleton's diction have been extensively, but not exhaustively, listed by Oliphant and Eccles.<sup>16</sup> Among these habits are the constant use of contractions (such as *h'as*), gallants' oaths and ejaculations, syntactical oddities, fondness for airing his Latin, and a variety of characteristic locutions (such as *aloof off*). Middleton never loses an opportunity to deride lawyers.<sup>17</sup> Unlike

<sup>14</sup> For criticisms of Middleton see Ellis-Fermor, *op. cit.*, pp. 128-132; W. D. Dunkel, *The Dramatic Technique of Thomas Middleton in His Comedies of London Life* (Chicago, 1925), pp. 52, 96, and *passim*; P. G. Wiggin, *An Inquiry into the Authorship of the Middleton-Rowley Plays* (Radcliffe College Monographs, No. 9), p. 45; E. H. C. Oliphant, "The Bloody Banquet. A Dekker-Middleton Play," *London Times Literary Supplement* (December 17, 1925), p. 882; A. Symons, "Middleton and Rowley," *Cambridge History of English Literature* (New York, 1910), pp. 71-74.

<sup>15</sup> Oliphant, E. H. C., "The Authorship of *The Revenger's Tragedy*," *Studies in Philology*, 23 (1926): 159.

<sup>16</sup> See the articles by Oliphant (notes 14 and 15) and M. Eccles, "Middleton's Birth and Education," *The Review of English Studies*, 7 (1931): 430.

<sup>17</sup> Wiggin, *op. cit.*, p. 10.

Dekker, he rarely refers to or borrows from the plays of his contemporaries.

## II

In studying the collaboration of Webster and Dekker, Pierce employs a "three-syllable Latin word test" as an aid in distinguishing the work of the dramatists. Though recognizing the limitations of this test, as pointed out by Rupert Brooke and F. L. Lucas, I think it has enough validity to justify its use in conjunction with other tests, and I therefore employ it here. Pierce's method is to figure the percentage of three-syllable words of Greek or Latin origin per solid prose line, using the Dyce edition of Webster for unit of content. In adopting this test I have altered it to the extent of counting the total number of words in the play rather than the total number of solid lines, but my findings remain comparable to Pierce's.<sup>18</sup> Middleton's percentage of Latin trisyllables ranges from 3.2 in *Your Five Gallants* to 3.9 in *A Trick*; his average in the four London comedies (*Michaelmas Term*, *A Mad World*, *Your Five Gallants*, and *A Trick*) is 3.52 per cent. On the other hand, Dekker's percentages for the four plays of *Old Fortunatus*, *Satiromastix*, *Match Me in London*, and *The Shoemaker's Holiday* (four plays entirely his) range from 2.47 per cent in *Old Fortunatus* to 1.16 per cent in *The Shoemaker's Holiday* and average 1.8 per cent. In only four of the ten plays by Dekker that Pierce examined does Dekker rise above 2 per cent in the number of Latin trisyllables,<sup>19</sup> a fact which contrasts sharply with Middleton's average.

*The Roaring Girl* is composed of 994 prose and 1,494 verse lines, the latter being 60 per cent, a figure much higher than we should expect from Middleton in 1604, for the other London comedies have from 22 to 35 per cent of verse. The explanation is, doubtless, the presence in this play of a romantic plot; but Middleton's tendency was constantly toward more verse. Only one scene of the play,

<sup>18</sup> Pierce, *op. cit.*, pp. 6-8. In counting trisyllables I have used Pierce's criteria for Latin words (so far as they are stated), as given on page 7. Words in which two thirds of the syllables are Latin or Greek, radical syllables included, are counted, even though Germanic affixes have been added.

<sup>19</sup> *Ibid.*, p. 8. Scenes in *Satiromastix* may have been suggested or possibly written by Marston, but the play is largely Dekker's. Hunt, *op. cit.*, p. 70; R. A. Small, "The Stage Quarrel," *Forschungen zur englischen Sprache und Literatur*, Heft I (Breslau, 1899), p. 122.

however, is wholly in verse — the last one. The scene in which Dekker is most evident (V, 1) is largely in prose.

The play is decidedly Middletonian in that, despite the romantic love plot which brings Moll Cutpurse most into the action, episodic realistic intrigue makes up not only all of the shopkeeper's subplot, but a large part of the main plot. Contrasting a romance with an action of cynical and realistic humor is characteristic of Middleton. The link connecting the plots is the movement of several characters such as Moll, Laxton, Goshawk, and Greenwit from one action to the other. This unification is conventional and somewhat tenuous, but stronger than in plays Dekker wrote unaided.

I shall glance through the play scene by scene, following Dyce's division; the quarto has no act or scene indications except the label at the beginning "*Actus Primus, Scaena Prima.*" It is, of course, essential to consider whether Dyce's division reflects with any accuracy the division of work between the two playwrights, for if it does not, it is only a hindrance to analysis of their parts. But here, as elsewhere, Dyce did good work, and I find nothing to change; his scene division corresponds with the probable shares of the dramatists, except in Act I, which he did not divide into scenes.

## ACT I

Taken as a single scene, Act I has a total of 296 verse and 53 prose lines; its percentage of feminine endings is 24.3; of rhyme, 42.5; and of run-on lines, 26.6. If we use as norms for judging these figures the averages mentioned above (for Middleton, 20 per cent of rhyme, 33 of double endings, 3.5 of Latin trisyllables; for Dekker, 59 per cent of rhyme, 11 of double endings, 1.8 of trisyllables), it is apparent that Act I is a fusion of the writers' styles. Although we can divide the act into scenes, distinguishing the authors' shares by this means is less decisive than in later acts.

Act I may be divided into three scenes, that of Sebastian's interview with Mary, that of Sir Alexander's discourse to his son and guests, and that of Sir Alexander's conversation with Trapdoor. When these scenes are tested individually the results in percentages are as given in Table I.

The figures for rhyme and double endings suggest that Dekker drafted Scene 1 and Middleton Scenes 2 and 3, and there are a few

TABLE I

|                  | Rhyme | Double and<br>triple endings | Trisyllabic<br>words | Run-on<br>lines |
|------------------|-------|------------------------------|----------------------|-----------------|
| <i>Scene 1</i>   |       |                              |                      |                 |
| Prose, 34 lines  |       |                              |                      |                 |
| Verse, 75 lines  | 56.0  | 20.0                         | 3.7                  | 36              |
| <i>Scene 2</i>   |       |                              |                      |                 |
| No prose         |       |                              |                      |                 |
| Verse, 184 lines | 42.3  | 27.1                         | 2.4                  | 22.8            |
| <i>Scene 3</i>   |       |                              |                      |                 |
| Prose, 20 lines  |       |                              |                      |                 |
| Verse, 37 lines  | 16.2  | 24.3                         | 0.7                  | 27              |

other indications to corroborate the impression — the ironies of the language and situation, the number of asides, and the relatively full characterization of the "heavy" father, a type which Dekker leaves a mere blind force in *The Honest Whore* and *The Shoemaker's Holiday*. But there are verbal traces of Dekker<sup>20</sup> which, with the high percentage of rhyme, make it impossible to rule out his hand in these two scenes also.

That Dekker helped plan the play is to be noted here. The romantic plot, with an avaricious father opposing true love, the hatred of forced marriage, the simple, sentimental conceptions of love and feeling, the employment of the old soldier, the magniloquence of the servant Neatfoot<sup>21</sup> are customary with Dekker. Such names as "Sir Guy Fitzallard," "Sir Alexander Wengrave," and "Sebastian" have the quality of those in Dekker's romantic love plots; others, like "Sir Davy Dapper" and "Sir Adam Appleton," might be the invention of either partner; still others, like "Goshawk," "Greenwit," and "Laxton," are clearly Middleton's.

As an examination of the remaining acts will show, the playwrights seem to have worked by dividing their project so that each did scenes from both romantic and realistic plots. But this assumption does not apply to Act I, for which we must suppose either that it

<sup>20</sup> *Rat's-bane*, *ape*, *varlet*, *shipwreck*, *subtlety* (in the sense of "weapon"), *goll*, and *beat* are favorites of Dekker, and occur throughout the act; images of sea storms occur frequently at the beginning. Cf. "Make not poor sorrow proud with these rich tears" (*The Shoemaker's Holiday* IV, 1) with "his eyes were richer even by that which made them poor . . ." in lines 192-193.

<sup>21</sup> Hunt, *op. cit.*, p. 112.

was drafted by Dekker and then thoroughly revised by Middleton or that Dekker outlined the plot and wrote Scene 1 and that Middleton wrote Scenes 2 and 3 in imitation of the style of Scene 1, and later retouched Scene 1. We know from the Foreword to *The Family of Love* that Middleton made some preparations for printing; the fullness of stage directions in *The Roaring Girl* hints that he may have revised the play before printing. In any event, both writers are in evidence in Act I.

## ACT II

*Scene 1.* The percentage of double endings (32) is higher than that of any other scene in the play; the rhyme is merely the usual concluding couplet. The number of trisyllabic words (2.9 per cent) is too high for Dekker's style. Both verse and vocabulary are distinctive of Middleton.

The scene is typical of the London comedies, one in which gallants and citizens mingle in street or shop to intrigue or cheat, vulgarly and gaily. Characteristic of Middleton are the frequent easy transitions from prose to verse, ironic asides, dramatic irony of schemes exposed and concealed, flirtatious city wives. Other indications of Middleton are the use of such expressions as *pish*, *i'faith*, *heart*, *pooh*, *troth*, *ha't*, *'thas*, *for't*, *sh'as*, *ith* *suburbs*, and *sir* many times repeated. The dialogue has Middleton's "smartness and rapidity."<sup>22</sup> In the part of Moll Cutpurse would be the likely place to look for Dekker's hand; but the quality of her speech is like that of the other gallants, except in so far as her nature is better. The charitable view of her here and throughout the play may have originated with Dekker, but more justly should be credited to Middleton.

*Scene 2.* Again, the large number of feminine endings (27.9 per cent) and trisyllabic words (2.6 per cent) and the small number of rhymes (23.5 per cent) show the work of Middleton. The irony of the action supports this belief. Sir Alexander, as eavesdropper, unaware that he is detected, reveals alternate pleasure and pain in his comic asides; and Moll's wit is heightened by her ignorance of the part she is playing in Sebastian's little farce. If Dekker had a part in this scene, we might look for it, not here or in the Tailor's *doubles-entendres* (which are too vivacious for Dekker), but in the

<sup>22</sup> Bullen's phrase, *op. cit.* (see note 7), I : xxxvii.

sententious dialogue between father and son at the end; yet this also has Middleton's peculiar contractions (e.g. *a'th'good man*) and cadence of verse:

.....If thou long'st  
To have the story of thy infamous fortunes  
Serve for discourse in ordinaries and taverns,  
Thou'rt in the way; or to confound thy name,  
Keep on, thou can'st not miss it; or to strike  
Thy wretched father to untimely coldness,  
Keep the left hand still, it will bring thee to't.

### ACT III

*Scene 1.* This also is Middleton's. The percentage of trisyllables is low (2.2), but so also is the rhyme (9), and the feminine endings are double Dekker's average (28). The diction is unmistakably marked by expletives like *heart, life, pox, and faith*; by contractions like *for't, 'thas, sh'as, bear't, and 'thad*; by repetition of *sir*; and by words like *company, despatch, and conscience*. As in the preceding scene, "the high German," a noted duelist, is referred to. The speech again has Middleton's pithiness and speed. I find no evidence of Dekker even in Moll's long moralizing speech, in phraseology characteristically Middleton's.

Teach thy base thoughts manners: thou'rt one of those  
That thinks each woman thy fond flexible whore;  
If she but cast a liberal eye upon thee,  
Turn back her head, she's thine . . . .

It is pleasant that this scene, demonstrating the nobility in Moll, refutes the assertion that Middleton could not draw feminine character except cynically.

*Scene 2.* The numbers of trisyllables (3.1 per cent) and feminine endings (57.5 per cent) are high. The rhyme is more than double Middleton's average (69.6 per cent), but since the lines of verse are relatively few, the verse tests are not conclusive. However, the Latinized diction, the same linguistic peculiarities that were noted in Scene 1, and the rich comic irony of this scene, typical of his technique, point to Middleton. Dyce, it is true, calls attention to a close verbal parallel in *The Whore of Babylon*, but, as Bullen says,<sup>22</sup> the whole scene is paralleled in *A Trick to Catch the Old One*. If

<sup>22</sup> *Op. cit.* (see note 7), p. 72.

Dekker did any of this scene, it might have been the melodramatic rhyming speeches of Mistress Gallipot, but just as probably Middleton wrote them as an ironic parody of romantic style. Satire of the citizens' wives pervades the action and language of the scene.

*Scene 3.* A large part, perhaps all of this, is by Dekker. Possibly Middleton planned it and probably he retouched it. Among the traces of his hand are the gratuitous jibes at Puritans and lawyers and such expressions as *pish*, *at's*, *break's*, *i'th'Hole*, *upo'th'back*, *i'faith*; and the percentage of trisyllabics (2.5) is a little high for Dekker.

But the evidence for Dekker is strong. Feminine endings are few (18.6 per cent); rhymes are numerous (44.1 per cent). The humor of the scene is broader and relies heavily on puns on such words as *son*, *male*, and *counter-tenor*. The characters are inclined to speak in chorus. Sir Davy's speech lapses into uncharacteristic vehemence: "There, boy, there, boy! away: look to your prey, my true English wolves; and so I vanish." Such expressions as *varlet*, *ningle*, *circle*, and *dry beat* are common in Dekker, and the verse has his cadence, even relapsing into doggerel once or twice:

You two are villainous loads on gentlemen's backs;  
Dear ware this Hanger and this Curtlex!

Finally, the overlong disquisition on the Counter prison and its degrees, rhymingly pronounced by Sir Alexander, is out of character, has a striking verbal parallel<sup>24</sup> to a line in *The Whore of Babylon* (1607), and is surely Dekker himself speaking from experience.

## ACT IV

*Scene 1.* The trisyllables (2.8 per cent), the feminine endings (31.2 per cent), and the rhyme (8.9 per cent), all indicating Middleton, are corroborated by the vocabulary and the action. Besides the expletives and contractions already noticed several times, we find *is't*, *steal't*, and *thou'st*. Further evidences of Middleton are the length and the number of asides and the irony, especially in Sebastian's attempt to disguise Moll, for whom his father has laid the trap, and in the father's frustration.

Miss Hunt has pointed out the absence of love passages in this

<sup>24</sup> " . . . these men-midwives must bring him to bed i'the Counter"; in *The Whore of Babylon* we find " . . . men midwives that neuer bring people to bed . . ." (quoted in Bullen, *op. cit.* [see note 7], IV: 88).

scene as proof that Dekker had no part in it.<sup>25</sup> The observation is true; the rendezvous is occupied by Moll's talk and song. The versification is in Middleton's easy cadences.

*Scene 2.* Although there are suggestions of Middleton's work here, chiefly linguistic ones, contractions and ejaculations of the kind found in earlier scenes, they are much rarer than in Middleton's uncollaborated work. Bullen points out what looks like a touch by Middleton, the reference to archery on Bunhill, and cites a record of Middleton's services there in 1623;<sup>26</sup> but the date has no value. On the other hand, Dekker, who wrote a poem, now lost, called "The Artillery Garden,"<sup>27</sup> was equally able to make the comparison, as were many other Londoners.

Indeed, the evidence points clearly to Dekker. The man who wrote III, 3 wrote this scene also; he repeats *tilt* for "cohabit," the image of spitting poison in the face, *puttock*, and *varlet*. Act II, Scene 1, of *The Honest Whore*, Part I, corresponds in the use of *Udsoul*, *take fresh salmon* ("use a prostitute"), and *soused gurnet*. In fact, Dekker's violent Billingsgate contrasts with Middleton's limited resources; in this scene we find the epithets *goat*, *baboon*, *pocky-nosed rascal*, *gib* (Dekker often alludes to cats), and *lame gelding*, and an ebullience of language which corresponds strikingly with Bellafront's talk to Roger and the gallants in *The Honest Whore*. To be noted also are the easy puns (on *light* and *bearing*), the chorus effect in the speeches, the nautical and piscatorial figures of speech, and allusions to three popular plays, *Westward Ho!*, *A Knack to Know an Honest Man*, and *Friar Bacon and Friar Bungay*. There is a verbal parallel with *The Shoemaker's Holiday*.<sup>28</sup>

In mood and attitude this scene contrasts with Middleton's representation of citizens. Instead of ironic satire we are shown an unimpressive pseudo-morality converting Mistresses Gallipot and

<sup>25</sup> *Op. cit.*, p. 111.

<sup>26</sup> *Op. cit.* (see note 7), p. 101.

<sup>27</sup> Dated 1616. A. H. Bullen, "Dekker, Thomas," *Dictionary of National Biography* (New York, 1888), XIV: 300.

<sup>28</sup> ".....'cause he seeks t'untie  
The knot God fastens, he deserves most to die."

— *The Roaring Girl*

"That any hand on earth should dare untie  
The sacred knot, knit by God's majesty . . ."

— *The Shoemaker's Holiday*, V, 5



Openwork to rectitude and the delightfully foolish Master Gallipot into a surly wronged husband who finally invites his enemy to dinner. It was necessary to end the minor plot.

In the versification, 14.5 per cent of feminine endings and 46.6 per cent of rhyme indicate Dekker, as does the 1.8 per cent of trisyllabic words.

## ACT V

*Scene 1.* This is the noted canting scene, unanimously ascribed to Dekker by all critics who have read *The Belman of London* or *Lanthorne and Candlelight*. Dekker's peculiarities are obvious from the first sentence to the last. The thieves' jargon is uniquely his. Without stopping to catalogue linguistic evidence I merely instance the vehement, repetitious speech of all characters, the speaking in chorus, Trapdoor's grandiloquence, the interest in the profession of the old soldier, the remarks about debtors' prisons, and the display of Latin, Spanish, Italian, and Dutch phrases (Dekker had an unusual knowledge of Dutch). The verse in which Moll speaks is free from feminine endings and is much rhymed.

Among the surprising elements in this irrelevant, undramatic scene are the introduction of four new characters (one, Lord Noland, being rather important throughout the act), the change of Jack Dapper from indecisive fool to confident braggart, and Moll's defense of her good name. Middleton would hardly have repeated this defense, already made in III, 1. His style is nowhere observable in this scene; apparently he did not retouch or prune it. So awkwardly does this long interlude fit into the play that I surmise it is either an expansion of an episode or two which proved such a hit in the theater that Dekker rewrote them at length, or a scene Dekker had written before the rest of the play was composed or conceived. The chances are that its popularity caused Middleton to leave it unaltered in the quarto.

*Scene 2.* This scene, wholly in verse, was done by Middleton. The feminine endings are 34.4 per cent, the rhyming lines 13.9 per cent, and the trisyllabic words 3.5 per cent. Though the verse is unusually regular for Middleton, he was not incapable of adapting his style to the romantic mood and the tone set by Dekker in the first act. There is no real evidence, linguistic or otherwise, of Dekker in this scene.

Such terms as *take't*, *to't*, *prodigal*, *comfort*, *hoyda*, *plunge*, *gentlemen* (often repeated), and *sir* as a redundant syllable are but part of the linguistic evidence for Middleton. Trapdoor's resumption of plain English, Sir Alexander's developing humanity as he is chastened, and the bringing on of the shopkeepers and their wives for the full-stage conclusion, though they have nothing to say — all these suggest Middleton. The general atmosphere of love feast which closes the play might have been influenced by the sentimental Dekker, but the verse in which it is conveyed does not differ technically from that at the beginning of the scene.

### III

Table II shows that Dekker composed a little less than half of the play — around 951 lines to Middleton's 1,537. How was the work planned and executed?

The romantic plot recalls Dekker's usual romantic themes; but, as the preceding analysis shows, Middleton's management gives it life. The shopkeeper-gallant intrigue was originated and developed by Middleton, but concluded by Dekker. Except for the canting scene (a negligible dramatic contribution), Dekker has almost nothing to do with the depiction of Moll. Since a collaboration is not a mechanical division, but a chemical synthesis, it is foolish to insist that Dekker had an insignificant part in the creation of the literary Moll Cutpurse, who, as T. S. Eliot thinks, does honor to her sex, second only to Miranda; though Eliot does not think so, Dekker may have furnished much of the fine feeling which makes of her "a free and noble woman." But the evidence offered by this study, together with the excellent "Epistle to the Reader," confirms Middleton's larger responsibility for her.

To bind these plot elements into passable unity Moll is made to move in both romantic and realistic intrigues; minor characters like Laxton, Goshawk, Jack Dapper, and Noland appear in both. Thus the vague association of Sebastian with the gallants is the underlying bond between the two levels of action. The plan of construction seems to me to reveal more effort to attain unity than Dekker normally made, and may plausibly be attributed to Middleton, but has no further significance.

The table also shows that the dramatists' collaboration was

TABLE II: METRICAL AND LINGUISTIC ANALYSIS OF *THE ROARING GIRL*  
(Dekker, 951 lines; Middleton, 1537 lines)

|                    | Prose lines | Prose: 994 lines; verse: 1494 lines; total: 2488 lines |                             |                                |                                 | Authorship                        | Authorship as assigned by other critics *             |
|--------------------|-------------|--------------------------------------------------------|-----------------------------|--------------------------------|---------------------------------|-----------------------------------|-------------------------------------------------------|
|                    |             | Verses lines                                           | Percentage of rhyming lines | Percentage of feminine endings | Percentage of trisyllabic words |                                   |                                                       |
| Act I<br>Scene 1   | 34          | 75                                                     | 56.0                        | 20.0                           | 3.7                             | Dekker (revised by Middleton)     | Dekker: Bullen, Fleay, Hunt, Symons                   |
| Scene 2            | ..          | 184                                                    | 42.3                        | 27.1                           | 2.4                             | Middleton (with help from Dekker) | .....                                                 |
| Scene 3            | 20          | 37                                                     | 16.2                        | 24.3                           | 0.7                             | Middleton (with help from Dekker) | Middleton and Dekker: Sykes                           |
| Act II<br>Scene 1  | 281         | 53                                                     | 3.7                         | 32.0                           | 2.9                             | Middleton                         | M.: Bullen, Hunt, Symons; M. and D.: Sykes; D.: Fleay |
| Scene 2            | 56          | 136                                                    | 23.5                        | 27.9                           | 2.6                             | Middleton                         | M.: Fleay, Sykes; D.: Bullen, Hunt, Symons            |
| Act III<br>Scene 1 | 93          | 110                                                    | 9.0                         | 28.0                           | 2.2                             | Middleton                         | M.: Bullen, Hunt, Symons; M. and D.: Sykes; D.: Fleay |
| Scene 2            | 79          | 66                                                     | 69.6                        | 57.5                           | 3.1                             | Middleton                         | M.: Bullen, Hunt, Symons; M. and D.: Sykes; D.: Fleay |
| Scene 3            | 104         | 86                                                     | 44.1                        | 18.6                           | 2.5                             | Dekker (revised by Middleton)     | M.: Bullen, Hunt; M. and D.: Sykes; D.: Fleay, Symons |
| Act IV<br>Scene 1  | 25          | 178                                                    | 8.9                         | 31.2                           | 2.8                             | Middleton                         | M.: Bullen, Fleay, Hunt, Sykes; D.: Symons            |
| Scene 2            | 101         | 206                                                    | 40.6                        | 14.5                           | 1.8                             | Dekker                            | M.: Symons; M. and D.: Bullen, Hunt; D.: Fleay, Sykes |
| Act V<br>Scene 1   | 252         | 47                                                     | 42.5                        | 12.7                           | 2.8                             | Dekker                            | D.: All                                               |
| Scene 2            | ...         | 316                                                    | 13.9                        | 34.4                           | 3.5                             | Middleton                         | M.: Fleay; M. and D.: Sykes; D.: Bullen, Hunt, Symons |

\* See Bullen, *op. cit.* (note 7), I: xxvi-xxviii; F. G. Fleay, *A Biographical Chronicle of the English Drama, 1559-1642* (London, 1891), I: 132; Hunt, *op. cit.*, p. 111; Sykes, *op. cit.*, p. 224; Symons, *op. cit.*, p. 75.

conducted more on the principle of an equitable division of labor than on any exclusive plan of plot, theme, act, or scene division; perhaps the phrase that most nearly describes their method is "a combination of plot division and scene division." Lawrence and Oliphant agree that three out of four times the evidence of two hands in the same scene means a later revision by one author.<sup>20</sup> I suspect that Middleton retouched portions of Dekker's work before publication, especially the first half of Act I and Act III, Scene 3, and that he inserted stage directions likely to be needed by a reader, probably those in II, 1 (his own scene), such as "At the Sempsters shop now," "At the Tobacco shop now," and one, at least, in IV, 2 (Dekker's scene), in which we find the odd expression *aloof off*, which occurs in *Michaelmas Term* and *A Mad World*, but which I have never seen in Dekker.

#### SUMMARY

The results of tests of versification and diction, together with study of the preferred themes, the characterization, and the constructive skill of the two writers, show that Dekker composed about two fifths of the play. This amount includes an equal share of Act I and, in later acts, certain scenes from both romantic and realistic intrigues; but the major development of both plots was written by Middleton. Dekker concluded the realistic plot; Middleton began the realistic and finished the romantic one.

The collaboration was closest in Act I. Although Dekker's manner is most easily discernible in Scene 1, he doubtless contributed much to the shaping of the romantic plot and to the characterization in Scenes 2 and 3. But since Middleton actually wrote all except 200 lines of the romantic action in the remainder of the play, he should be credited with the most memorable character in this drama, Moll Cutpurse. After composing Act I the authors seemingly wrote their shares more independently. There is some evidence that Middleton revised the whole play, none that he pruned it.

MICHIGAN STATE COLLEGE

<sup>20</sup> Lawrence, W. J., *Pre-Restoration Stage Studies* (Cambridge, Mass., 1927), p. 366; E. H. C. Oliphant, "Collaboration in Elizabethan Drama: Mr. W. J. Lawrence's Theory," *The Philological Quarterly*, 8 (1929): 5.



## MISINTERPRETATIONS OF EPICUREAN DOCTRINE IN THE *ANTI-LUCRÈCE* OF CARDINAL DE POLIGNAC

LINTON C. STEVENS

THE proponents of Cartesianism were not lacking in the eighteenth century in spite of the attacks of the *philosophes*. Cardinal de Polignac was easily the most distinguished of those who clung to the outmoded ideas.<sup>1</sup> He even made a real effort to absorb the new ideas of Hobbes, Locke, and Newton, but he misinterpreted them to a great extent. There have been several studies of Polignac's poem, the *Anti-Lucrèce*, but one finds in these monographs a quite inadequate treatment of his ethical ideas. They have, however, analyzed rather exhaustively his ideas of the physical sciences and his errors in respect to the English philosophers. The more recent books, P. Paul's biography of 1922, C. Fusil's *Anti-Lucrèce* of 1918, and W. Menzel's *Der Kampf gegen den Epikureismus in der französischen Literatur des 18. Jahrhunderts* of 1931, have been curiously silent about the first modern study of the poem, E. Patry's *Anti-Lucrèce* of 1872. They have all failed to comment on the reception of the poem by contemporaries and contemporary criticism.

The ten-thousand-line Latin poem, the *Anti-Lucrèce*, obtained a most favorable hearing both at court and in the fashionable salons of the eighteenth century, even though it was not published until 1747, five years after the author's death. When Polignac returned to the court in 1702, after a short period of retirement, which had been the unhappy result of his diplomatic errors, he found that rumors concerning his poem had already excited general curiosity. The eighteenth-century biographer C. Faucher made this assertion:

<sup>1</sup> Bouillier, F., *Histoire de la philosophie cartésienne* (Paris, 1868), II: 536: "Voltaire croit pouvoir fixer à l'année 1730 le commencement de cette décadence de la philosophie de Descartes: 'Ce n'est guère, dit-il, que depuis l'année 1730 qu'on a commencé à revenir en France de cette philosophie chimérique, quand la géométrie et la physique expérimentale ont été plus cultivées.'"

"No sooner had people heard of the *Anti-Lucrèce* (although only as a slight sketch) than their curiosity was aroused because of the high opinion which they had of his [Polignac's] genius and his learning; the most learned and distinguished people of the court and the city were eager to hear it read or to possess copies of it. The Duchesse de Maine, who had successfully studied many branches of science, was eager to learn what the *Anti-Lucrèce* contained. The Abbé de Polignac, who was an illustrious member of her court, gave her an oral translation of it from one end to the other. The Duc de Maine, who was as cultivated as his wife, translated the first book, and dedicated it to his wife in an epistle worthy of the person to whom it was addressed."<sup>2</sup>

We can also judge of the importance which Polignac's poem must have assumed in the eyes of contemporaries from the frequent allusions to it in the works of Voltaire. Voltaire includes Polignac in the *Temple du Goût* and speaks of him in flattering terms:

Le Cardinal, oracle de la France  
Non ce mentor qui gouverne aujourd'hui,  
Mais ce Nestor qui du Pinde est l'appui;  
Qui des savans a passé l'espérance,  
Qui les soutient, qui les anime tous,  
Qui les éclaire, et qui règne sur nous  
Par les attrails de sa douce éloquence,  
Ce cardinal qui, sur un nouveau ton,  
En vers latins fait parler la sagesse,  
Réunissant Virgile avec Platon,  
Vengeur du ciel, et vainqueur de Lucrèce . . . ."<sup>1</sup>

In an article on Newton, however, Voltaire has already changed his opinion and refers to the cardinal's philosophical pretensions with considerable disdain. He criticizes him politely but severely: "Of all those who have been in the society of the Cardinal de Polignac, there is no one who has not heard him say that Newton was a Peripatetic, and that his colorific rays, and especially his theory of attraction, smacked of atheism. The Cardinal de Polignac joined great eloquence to all the advantages which he received from nature; he wrote Latin verses with astonishing and felicitous facility; but he knew only the philosophy of Descartes and he had learned his reasoning by heart as one learns dates. He had not become a

<sup>1</sup> Faucher, C., *Histoire du Cardinal de Polignac* (Paris, 1780), II: 8-9.

<sup>2</sup> Voltaire, *Œuvres complètes* (Desoer, Paris, 1817), III: 479.

geometrician, and he was not born a philosopher. He could judge the Catiline orations and the *Aeneid*, but not Newton and Locke." <sup>4</sup>

In another place Voltaire seems to imply that he has judged the poem too hastily at first, probably because of Polignac's eloquent delivery. <sup>5</sup> "He had formerly read to me twenty verses which appeared very fine: the Abbé de Rothelin assured me that the rest was much superior. I took Cardinal de Polignac for an ancient Roman and for a man superior to Virgil: but, when his poem was printed, I judged it for what it is, a poem without poetry, and philosophy without reason." This severe reproof delivered by a mature Voltaire does not reflect the enthusiasm aroused by the *Anti-Lucrèce* in the early part of the century.

The occasion which gave rise to the poem is most succinctly expressed by the introduction to the London edition of 1748: "When the Abbé de Polignac returned from Poland in the year 1697, he stayed some time in Batavia, and had several conversations with that very sagacious man Pierre Bayle, who was in darkest ignorance in matters of religion. Therefore, zealous for truth and virtue, he conceived this great work in which he might overthrow in hand-to-hand combat Lucretius, the master and oracle of the atheists." <sup>6</sup>

What should interest us particularly in the *Anti-Lucrèce* is not its philosophical importance, which is negligible, but its interpretation of current philosophical ideas by a literary spokesman of a group opposed to the *philosophes*. At the beginning of the sixteenth century there had been a marked recrudescence of interest in the doctrines of Epicurus. In 1516 Pomponazzi manifested some doubt concerning the immortality and the immateriality of the soul. In 1591 Campanella founded knowledge on sensation. Later, Vanini, Maffei, Philelphe, and Valesco professed theories which resembled those of Lucretius. But it was especially Gassendi who exerted great influence by his discussion of Epicurean doctrines in his three works: *De vita et moribus Epicuri*; *Animadversiones in decimum librum Diogenis Laertii*; and *Syntagma philosophiae Epicuri*. In a recent article D. C. Allen has shown us that the two traditions about Epicurus, that of a degraded voluptuary and that of an idealist pursuing the highest type of intellectual pleasure, can be found in writers of the

<sup>4</sup> *Ibid.*, VII: 41.

<sup>5</sup> *Ibid.*, X: 158.

<sup>6</sup> Polignac, Melchior de, *Anti-Lucretius sive de deo et natura* (Londini, 1748), Introd. xi.



early Renaissance. Lorenzo Valla and Salutati followed the former and Ficino the latter.<sup>7</sup>

These doctrines, which found expression in those who belonged to the *Société du temple*, had ceased to exert any appreciable influence upon philosophical ideas after 1730. It is true, however, that the ethical doctrines acquired great importance later in the century. Lagrange translated Lucretius in 1768. The *Système de la nature* of the Baron d'Holbach, published under the pseudonym of Mirabaud, which was to become the credo of atheism and of materialism, did not appear until 1770. But the physical theories of Epicurus and Lucretius which Polignac attacks so violently were taken seriously by very few people.<sup>8</sup>

The ideas of Polignac show the persistence of a popular tradition about Epicureanism. He sees only the degenerate, degraded Epicureanism combined with the Cyrenaicism professed by the libertines, the impious, and the unbelievers of his time. Lucretius did not advocate sensual and debased pleasures. He professed a morality as pure as it could be prior to the establishment of Christianity. It seems rather strange, then, as W. Menzel points out, that C. Fusil should have asserted that Polignac explains the four great systems of Epicurus, Descartes, Spinoza, and Newton with the greatest clearness and exactness.<sup>9</sup>

Polignac's complete misinterpretation of Lucretius and Gassendi might have been strongly influenced by Lactantius, who, in refuting Lucretius, claims that the most inhuman actions result from the pursuit of pleasure and cites the example of Nero setting fire to Rome to give himself a new sensation.<sup>10</sup> C. Faucher tells us that Polignac consulted Malebranche concerning the philosophical doctrines of his poem. And yet, if we are to believe Bayle, Malebranche

<sup>7</sup> Allen, D. C., "The Rehabilitation of Epicurus and His Theory of Pleasure in the Early Renaissance," *Studies in Philology*, 41 (1944): 5-10.

<sup>8</sup> Patry, E., *L'Anti-Lucrèce du Cardinal de Polignac* (Auch, 1872), p. 11.

<sup>9</sup> Menzel, W., *Der Kampf gegen den Epikureismus in der französischen Literatur des 18. Jahrhunderts* (Breslau, 1931): "Das muss gegen Fusil bemerkt werden, der in seinem Werk über den Anti-Lukrez diese unbestreitbare Tatsache an mehreren Stellen zwar zugibt (22; 44; 49; 89; 99), aber doch an zwei Stellen (125 f.) davon spricht, dass der Kardinal die vier grossen Systeme des Epikur, des Descartes, Spinoza und Newton mit der denkbar grössten Klarheit und Exaktheit dargestellt habe."

<sup>10</sup> Paul, P., *Le Cardinal Melchior de Polignac* (Paris, 1922), p. 352.

supported a doctrine which Polignac does his best to combat. He made this statement: "M. Arnauld criticized vigorously this doctrine of Malebranche: 'All pleasure is good and makes the one who enjoys it really happy.'" <sup>11</sup> It is clear that Polignac interprets pleasure in the sense of Aristippus, that is, the pleasures of the body, whereas Epicurus admits, or rather emphasizes, the pleasures of the mind.<sup>12</sup> In Polignac, Book I, 471, we read: "There are some who, relying upon Gassendi as a leader, thus defend Epicurus and boast that they seek no pleasure except that which is obtained through virtue. These men are ignorant of this error covered by the name of virtue; they follow too patiently a deceitful man."<sup>13</sup> Gassendi, however, explains very clearly what Lucretius means by pleasure and identifies reason with *sapientia*. The *summum bonum* is *tranquillitas animi*. It is a permanent condition which must be reached through the mind by self-discipline. The condition which results is a pleasant state and, therefore, pleasure is in a sense the end of life.<sup>14</sup> Let us now examine Gassendi's definition of pleasure: "And first it is surprising that the name of pleasure (*hedone* or *voluptas*) should give rise to a fable, as Seneca observes, since one may include under this name not only obscene pleasures but chaste pleasures. For certainly Plato, Aristotle, and others are accustomed to distinguish some as pure, others impure, some of the mind, others of the body, some as true, some as false, and they may say 'does not Socrates in Plato demand for happiness the reasonable good of the *summum bonum* — not wisdom alone, not pleasure alone, but wisdom with pleasure?'" <sup>15</sup>

We see from this quotation that Polignac fails to understand that the *sapientia* or *ratio* of Gassendi does not differ from his own

<sup>11</sup> Bayle, P., *Dictionnaire historique et critique* (Rotterdam, 1720): "M. Arnauld critiqua de toutes ses forces cette doctrine du P. Malebranche. 'Tout plaisir est un bien, et rend actuellement heureux celui qui le goûte.'"

<sup>12</sup> Brett, G. S., *The Philosophy of Gassendi* (London, 1908), p. 185.

<sup>13</sup> "Sunt qui Gassendo freti duce, sic Epicurum  
Defendant, nullum ut jactent genus huicce petitem  
Esse Voluptatis, nisi quod Virtute paratur.  
Hi fraudem ignorant Virtutis nomine tectam;  
Fallacique viro nimium patienter adhaerent."

<sup>14</sup> Brett, *op. cit.*, p. 184.

<sup>15</sup> Gassendi, P., *Animadversiones in decimum librum Diogenis Laertii* (Third Edition, Lugduni, 1675), Vol. II, Part 3, p. 74.

*frenata voluntas*. If we confront the passage from Gassendi which we have just quoted with the following verses of Polignac, we see that he seems to have a rather naïve conception of virtue as a negative restraint only. Apparently he considers it impossible for an action to be both pleasurable and virtuous at the same time. "Pleasure therefore is not placed by you in virtue, but virtue in pleasure; so great is the art of duly enjoying nature, not of taming nature by reason; but virtue is nothing unless the disciplined will is made subject to the rule of virtuous reason and restrains all passions which rise in our breast and controls the conquered passions with a yoke whenever they rebel."<sup>16</sup> If Polignac had read Bayle's explanation of Epicureanism, he might have avoided this misinterpretation.<sup>17</sup> Epicurus recognized several kinds of pleasure, some in *tranquillitas*, some in *motus*, including *profligatorum voluptas*. Epicurus wished to follow nature. Gassendi takes it to mean "study your aptitudes," that is, choose the course of life that is most suited to your tastes.<sup>18</sup> Lactantius did not agree with it; Epicurus, he declared, aimed at popularity, and made base concessions to the frailty of human nature. He reproached him for his laxity in these terms: "Therefore, in order that he [Epicurus] may attract a crowd, he speaks things appropriate to the manners of each individual. He forbids the lazy to study literature; he frees the miser from being charitable; he forbids the slothful to enter the service of the State, the lazy man to exercise, the timid man to fight. The irreligious man hears that he need not sacrifice to the gods, the unsocial man is ordered to minister to his own needs and give nothing to anybody, for a wise

<sup>16</sup> *Anti-Lucretius*, Liber I, l. 493.

<sup>17</sup> Bayle, *op. cit.*: "Quant à sa doctrine touchant le souverain bien ou le bonheur, elle étoit fort propre à être mal-interprétée, et il en resulta de mauvais effets qui décrièrent sa Secte: mais au fond elle étoit très raisonnable, et l'on ne sauroit nier qu'en prenant le mot de bonheur comme il le prenoit, la félicité de l'homme ne consiste dans le plaisir. . . . le seul dogme, que l'on pouvoit établir raisonnablement selon cette route étoit de dire que la béatitude de l'homme consiste à être à son aise, et dans le sentiment du plaisir, ou en général dans le contentement de l'esprit. Cela ne prouve point que l'on établit le bonheur de l'homme dans le commerce impur que les sexes peuvent avoir l'un avec l'autre; car tout au plus ce ne peuvent [sic] être que des causes efficientes, et c'est de quoi il ne s'agit pas."

<sup>18</sup> Brett, *op. cit.*, p. 201. Gassendi (*op. cit.*, II: 430) stresses rather the passive contemplative pleasure: "Summum Bonum ab Epicuro fieri non voluptatem ullam in motu, sed illam potius quae est in quiete, vacuitateque perturbationis."

man does everything for himself." <sup>19</sup> According to Lactantius, Epicurus maintained that, if a man is lazy, he need not take exercise; according to Gassendi, the doctrine is, if nature has not intended you to be an athlete, do not try to become one. <sup>20</sup>

In spite of Polignac's frequent citations of Gassendi it is evident that he did not read him carefully, for he preferred to repeat the misinterpretations which he found in Ambrosius and Lactantius, although Gregorius Nazianzenus appears to have had a more just appreciation of Epicurus. <sup>21</sup>

In conclusion, we may say that Cardinal de Polignac adhered to the conception of Epicurus' doctrines which had prevailed through the seventeenth century, as M. Lachèvre has abundantly proved in his series of monographs entitled *Le Libertinage au dix-septième siècle*, and this interpretation was graphically presented in Sganarelle's characterization of his seigneur and master as a *pourceau d'Épicure*. His poem, then, which won the esteem and consideration of the court, if not of the philosophers, because of the prestige enjoyed by its author, represents a philosophical orthodoxy which the philosophers were doing their best to combat. It is true that the opposition to the *philosophes* was more important than has been commonly assumed. We are indebted to R. R. Palmer for an interesting exposition of this point in his *Catholics and Unbelievers in Eighteenth Century France* (1939). Nevertheless, since he fails to discuss our author, we feel justified in filling this lacuna. Polignac appears to renew a rather trite philosophical subject by his reference to Locke,

<sup>19</sup> Brett, *op. cit.*, p. 202.

<sup>20</sup> *Ibid.*, p. 203.

<sup>21</sup> Gassendi, *De vita et moribus Epicuri*, p. 150: "Plura sancti Patres obiciunt, ac nominatim B. Ambrosius, dum Epicurum appellat ebrum, et Voluptates patronum, irridere dicit ab iis, qui sobrii putantur Philosophi, etc." On the other hand, compare (*ibid.*, p. 106): "Ex istis unus est Lactantius, cuius cum libro tertio Institutionum verba sint, *Epicurus summum bonum in voluptate animi esse censet, Aristippus in voluptate corporis*." Also *ibid.*, p. 174, where Gassendi quotes Gregorius Nazianzenus:

"Ipsam voluptatem putavit praemium  
Epicurus exstare omnibus laboribus,  
Mortaliumque tendere huc bona omnia,  
Ac ne ob voluptatem improbam, haud laudatier  
Quis crederit, moderatus, et castus fuit,  
Dum vixit, ille, dogma moribus probans."

Hobbes, Spinoza, and Newton, whose doctrines he confuses in his general condemnation of Epicurus.<sup>22</sup>

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<sup>22</sup> Vol. I: ll. 593-595:

"Sed novus auxilio venit expirantis amici  
Defensor, Justum nativa lege doceri  
Qui negat, Hobbesius."

Vol. I: ll. 633-635:

"Jam verò commune bonum, quo nititur uno  
Hobbesius, ridenda viri commenta refellit,  
Et sua eum discors ludit Sententia."

Vol. I: ll. 667-669:

"Verum quisque sibi Deus et Rex; hanc ne libenter  
Incoleres? In ea velles traducere vitam?  
Spinosa teneant illam, teneant Epicuri."

Vol. II: ll. 865-869:

"Propterea miror tam docto, tamque sagaci  
Neutono Vacuum placuisse, ut motibus aptum  
Sideris. Etenim, dum certos atque perennes  
Astrorum cursus, cum vi obsistente fluenti  
Conciliare nequit . . . ."

Vol. II: ll. 646-649:

"Ergo vel Spatium tolli non posse Supremi  
Numinis arbitrio vult Lockius, atque Epicuro  
Consentit, paribusque volens prosternitur armis:  
Vel, si consentit nobis, temere ista docebat."

# WHO BEGAN THE REVIVAL OF LEARNING?

## THE RENAISSANCE POINT OF VIEW

HERBERT WEISINGER

WHO, in the opinion of the writers of the Renaissance, was most responsible for bringing about the revival of classical learning? This question was of serious interest to the humanists, and the answers they gave have a double significance. In the first place, the attempt to ascribe causes of the revival of learning as one aspect of the Renaissance indicates that the need was felt to explain cultural phenomena in some rational manner, for it was not enough to attribute the revival of learning to divine providence. In the endeavor to ascribe the Renaissance to nonsupernatural forces we can see a shift in the writing of history; human events are now being considered on the human plane. In the second place, to mark the beginning of the revival of learning with an individual is to date it, and this gives corroborating testimony to the view that the writers of the Renaissance were aware that the Renaissance happened in their own lifetime.

Of the men who were regarded as most responsible for initiating the revival of ancient learning Petrarch is by far the most frequently mentioned. While Petrarch was still alive Boccaccio defended him against attacks,<sup>1</sup> and soon after his death Coluccio Salutati wrote a long letter in which he listed Petrarch's accomplishments and declared that the whole world, and even nature itself, bewailed the loss of so great a scholar and poet.<sup>2</sup> In a later letter Salutati again mentions Petrarch's services in reviving ancient learning, and also singles out Dante and Boccaccio for praise.<sup>3</sup> Brunì writes of Petrarch:

<sup>1</sup> Osgood, Charles G., ed., *Boccaccio on Poetry; Being the Preface and the Fourteenth and Fifteenth Books of Boccaccio's "Genealogia Deorum Gentilium" in an English Version with Introductory Essay and Commentary* (Princeton University Press, 1930), p. 92.

<sup>2</sup> Salutati, Coluccio, "A Roberto Guidi Conte di Battifolle," No. 15, August 16, 1374, in *Epistolario di Coluccio Salutati*, ed. Francesco Novati (Rome, 1896), I: 176-187.

<sup>3</sup> *Idem*, "A Bartolommeo Oliari Cardinal Padovano," No. 9, August 1, 1395, *ibid.*, III: 84.

. . . Ed ebbe tanta grazia d'intelletto che fu il primo che questi sublimi studi lungo tempo caduti ed ignorati rivotò a luce di cognizione: i quali dapoi crescendo, montati sono nella presente altezza, della qual cosa, acciò che meglio s'intenda, facendomi addietro, con breve discorso raccontar voglio.<sup>4</sup>

Biondo also attributes the origin of the revival of ancient learning to Petrarch, and in a brief epitome of the history of the revival of learning and of the fine arts Aeneas Sylvius says:

. . . Videmus picturas ducentorum annorum nulla prorsus arte politas. Scripta illius aetatis rudia sunt, inepta, incompta. Post Petrarcham emerserunt literae. Post Iotum surrexere pictorum manus; utramque ad summam jam uidemus artem peruenisse.<sup>5</sup>

In his *Catalogus Scriptorum Ecclesiasticorum, sive Illustrum Virorum*, Johannes Trithemius has a place for Petrarch and says of him:

. . . Franciscus Petrarcha, natione Etruscus, vir in diuinis scripturis eruditus, & in secularibus literis omnium sui temporis longe doctissimus, philosophus, rhetor, & poeta celeberrimus, qui literas humanitatis post longa silentia mortuas (vt ita dixerim) ab inferis reuocauit ad superos, non minus sancta conuersatione quam scientia clarus emicuit.<sup>6</sup>

According to Vespasiano, it was Dante, Petrarch, and Boccaccio who revived the Latin tongue, which had been neglected for many centuries.

By the end of the fifteenth century the tradition that Petrarch had been the first to bring about the revival of ancient learning, or Petrarch with Dante and Boccaccio, was pretty well established. Despauterius, Vives, Parker, Leroy, Castiglione, and Scaliger, to mention but a few writers of the sixteenth century, carried on the tradition and gave it even greater currency. In a passage somewhat reminiscent of Leroy, Samuel Daniel shows that the tradition had been accepted in England:

. . . And is it not a most apparant ignorance, both of the succession of learning in *Europe* and the generall course of things, to say 'that all lay pittifully deformed in those lacke-learning times from the declining of the *Romane Empire*

<sup>4</sup> Aretino, Leonardo Bruni, "Vita di Dante e del Petrarca notizia del Boccaccio," in *Autobiografie e vite de' maggiori scrittori Italiani* . . ., ed. Angelo Solerti (Milan, 1903), p. 115. Cf. the similar statement made by Sico Polenton, *Scriptorum illustrium Latinae linguae libri XVIII*, ed. B. L. Ullman (American Academy in Rome, 1928), p. 139.

<sup>5</sup> Sylvius, Aeneas, No. 119, *Opera* (Basle, 1571), p. 646. Cf. Aeneas Sylvius' letter to Niklas von Wyle, July, 1452.

<sup>6</sup> Trithemius, Johannes, *Opera historica* (Francofurti, 1601), p. 322.

till the light of the Latine tongue was reuiued by Reweline, Erasmus, and Moore?<sup>7</sup> when for three hundred yeeres before them, about the comming downe of *Tamburlaine* into *Europe*, *Franciscus Petrarcha* (who then no doubt likewise found whom to imitate) shewed all the best notions of learning, in that degree of excellencie both in Latine, Prose and Verse, and in the vulgare Italian, as all the wittes of posteritie haue not yet ouer-matched him in all kindes to this day: his great Volumes in Moral Philosophie shew his infinite reading and most happy power of disposition: his twelue *Eglogues*, his *Africa*, containing nine Bookes of the last Punicke warre, with his three bookes of *Epistles* in Latine verse shew all the transformations of wit and inuention that a Spirite naturally borne to the inheritance of Poetrie and iudiciall knowledge could expresse: . . . And with *Petrarch* liued his scholar *Boccacius*, and neere about the same time *Iohannis Rauenenensis*, and from these, *tantum ex equo Troiano* [shades of Fichet!], seemes to haue issued all those famous Italian Writers, *Leonardus Aretinus*, *Laurentius Valla*, *Poggius*, *Biondus*, and many others.<sup>7</sup>

Daniel is, of course, criticizing Campion, but there is no guarantee that he knew Petrarch as well as he would have the reader believe, and the whole passage seems to be made up of unacknowledged quotations from Biondo, Fichet, Dolet, and Leroy.

When the notion that the revival of learning began *after* the fall of Constantinople in 1453 got into circulation I have been unable to determine, but this much is certain: it surely did not derive from the writers of the Renaissance. Bruni respected the learned Chrysoloras, who came to Italy as early as 1393, and a long succession of writers paid their respects to Chrysoloras and his fellow countrymen for the services they rendered in restoring the study of the Greek tongue to its former splendor. Filelfus, Stapulensis, Luther, Gyraldus, Politian, Dolet, Thevet, de Serres, and Daniel are but a few of the later writers to record the rôle played by the learned Greeks. The judgment of the sixteenth century in regard to Chrysoloras is well summed up by Thevet:

. . . Mais vn particulier bien est prouenu à la Chrestienté de ce furieux & turbulent siege, car durant iceluy Iean Paleologue despescha Emanuel Chrysolore pour aller demander secours à tous les Princes de l'Europe à l'encontre du Turc, qui vouloit s'emparer de la Grece. A grand peine nostre Chrysolore fust arriué en Italie, que nouuelles luy furent apportées de la desfaiete de Baiazeth au mont de l'Estoile. Qui fust cause d'y arrester ce Constantinopolitain, qui, ou pour la mort de Iean l'Empereur qu'aucuns disent estre interuenuë pendant le siege, ou bien pour le regret de veoir sa patrie si souuent exposée aux courses de ces voleurs, ne voulust reprendre voile en Grece. Partant se mist à enseigner le langue Grecque premierement à Venise, apres à Florence, finalement à Paue, où

<sup>7</sup> Daniel, Samuel, "A Defence of Ryme, Against a Pamphlet entitled: '*Observations in the Art of English Poesie*,'" 1603?, ed. George G. Smith, *Elisabethan Critical Essays* (Oxford: Clarendon Press, 1904), II: 368-369.



le Duc Jean Galeas l'honora de plusieurs & grands presens. D'une si rare & exquise plante, est sortie presque une infinité de iectons, les plus excellens qu'on puisse penser: & entre autres François Philelphe de Toledé en Espagne, (qui depuis print à femme la fille de son précepteur, de laquelle il eust deux filz Marius & Cyrus) Ambroise moyne de Colchestre en Angleterre, François Barbare Venitien, Charles & Leonard Aretius, Paulus Destroycy & infinité de plusieurs bons esprits, qui depuis ont publié la lotange de cest Emanuel par tout l'univers. Quelques uns ont voulu subtiliser sur son nom, & ont dict que ce nom d'Emanuel luy estoit escheu par un secret & divin presage de la restauration, qu'il devoit apporter des lettres Grecques en Italie, qui par l'espace de sept cens ans auoient demeuré atterrés (par la negligence de plusieurs, ou par la desbauche de ceux, qui devoient mettre la main à la besoigne, & ne tenoient conte des bonnes sciences) dans les vieilles mesures d'oubly. De vouloir penetrer si auant au Cabinet celeste ie ne pourroie, bien sçay-ie que l'Italie doit à bon droict de reputer pour celuy, qui luy a remis la cognoissance de la langue Grecque. Ce que Poge Florentin son disciple a bien recogneu en l'Epitaphe (qu'icy j'ay inferé) qu'il composa à Constance en l'honneur de son maistre, que estant là allé au Concile general y mourust.

Hic est Emanuel situs  
 Sermonis decus Attici,  
 Qui, dum quærere opem patriæ  
 Afflictæ studeret, huc yt.  
 Res bellè cecidit tuis  
 Votis Italia, hic tibi  
 Linguae restituit decus  
 Atticæ antè reconditæ.  
 Res bellè cecidit tuis  
 Votis Emanuel, solo  
 Consecutus in Italo  
 Æternum decus es, tibi  
 Quale Græcia non dedit  
 Bello perditæ Græcia.\*

Chrysoloras seems to have been regarded with the greatest respect and affection, but the other learned Greeks were not forgotten. The part played by the emigré Greeks in promoting the revival of ancient literature is thus fairly estimated by the Renaissance humanists.

A number of other individuals were credited with bringing about the revival of ancient culture. Bruni is occasionally mentioned; Palmieri attributes the revival to his friend, and Vespasiano speaks of Bruni, Poggio, and Fra Ambrogio as the first exponents of Latin. In the article "Literae" in his encyclopaedic *Commentarii linguae Latinae* Étienne Dolet considers Valla the first who instituted the

\* Thevet, André, *Les Vrais Portraits et vies des hommes illustres grecs, latins, et payens* . . . (Paris, 1584), pp. 97v-98r. Cf. Jean de Serres, *A General History of France* . . . , tr. Edward Grimestone (London, 1611), p. 380.

revival of ancient learning. In a passage which, as we have seen, Daniel criticized, Campion says:

. . . Learning first flourished in Greece; from thence it was deriued vnto the Romaines, both diligent obseruers of the number and quantity of sillables, not in their verses only but likewise in their proee. Learning, after the declining of the Romaine Empire and the pollution of their language through the conquest of the Barbarians, lay most pitifully deformed till the time of Erasmus, Rewcline, Sir Thomas More, and other learned men of that age, who brought the Latine toong again to light, redeeming it with much labour out of the hands of the illiterate Monks and Friers: as a scoffing book, entituled *Epistolae obscurorum virorum*, may sufficiently testifie.<sup>9</sup>

In the opinion of Bodin, Machiavelli was the first since the ancients to write on political science.<sup>10</sup> So far as I have been able to determine, Guicciardini seems to have been responsible for putting into circulation the idea that Lorenzo de' Medici introduced the Renaissance, an idea which ultimately culminated in England in William Roscoe's biography.<sup>11</sup>

As part of the nationalistic current which helped in the formation of the Renaissance, it became the custom to attribute the revival of learning as it took place in each country to the king then reigning. Thus it is interesting to note that Leroy has made a list of the ". . . Princes that haue most holpen the restitution of artes." He mentions Alphonsus, king of Naples; Francis I of France; the kings of Castile and Portugal, who were instrumental in ushering in the discoveries in both the east and the west; and Cosimo and Lorenzo de' Medici, whose libraries are especially mentioned.<sup>12</sup> By nationalism I mean the desire of groups of peoples to differentiate themselves from other groups because of their possession of certain characteristics which they are supposed to possess in common and which no other groups have. A part of the complex of nationalism is the wish to be preëminent in various fields of human endeavor, and the desirability of success in any field varies in accordance with what is considered a

<sup>9</sup> Campion, Thomas, "Observations in the Art of English Poesie," ed. Smith, *op. cit.*, II: 329.

<sup>10</sup> Bodin, Jean, *Methodus ad facilem historiarum cognitionem* (Lyons, 1583), p. 150.

<sup>11</sup> Guicciardini, Francesco, *The History of Italy from the Year 1490, to 1532. Written in Italian by Francesco Guicciardini, a Nobleman of Florence.* In Twenty Books. Translated into English by the Chevalier Austin Parke Goddard (London, 1753-56), I: 3-4.

<sup>12</sup> Leroy, Louis, *Of the Interchangeable Coorse, or Variety of Things in the Whole World . . .*, tr. Robert Ashley (London, 1594), p. 110v.

worth-while pursuit at any given time. In the period of the Renaissance the honor of being recognized as the leader in learning and in the practice of letters and arts was thought to be a highly commendable one and was eagerly sought after. The desire to carry away the palm of learning for one's country was therefore a strongly motivating force behind the work of the humanists.

In Italy, where the idea of national unity was practically unknown except in the minds of a few scholars and dreamers, patriotic zeal was transferred to the cities. Of the Italian cities where the new learning flourished Florence was almost universally held in the highest esteem. Ficino calls his century the golden age in which all the liberal arts are brought to light and are flourishing — and all that, he exclaims, in Florence! Though not a Florentine himself, Vespasiano feels compelled to acknowledge the preëminence of Florence and calls on Venice to follow suit. And Reuchlin and Melancthon, both foreigners, praise Florence as the leader in the study of the humanities. For the most part, the Italians take it for granted that the leadership in the new learning is theirs without dispute because they were the first to initiate the revival and because they had devoted so much time, energy, and treasure to it; the flocking of foreigners to the schools of Italy was to them a naturally expected homage to their position.

As the foreigners learned the new languages and grew proficient in their studies, they felt themselves capable of carrying on independent work which, they thought, ought to redound to the credit of their own country. As a consequence, they sought to compete with the Italians and even to vanquish them at their own game. In his *Liber Gnomagyricus* Tissard issues a challenge to his fellow humanists. The Italians scoff at us for our ignorance, he says, but we will show them what we can do:

Eh quoi! disent (les Italiens), . . . vous portez contre nous vos armes? Espérez-vous que vous puissiez jamais dominer dans notre patrie si célèbre, si éloquente, si policée? C'est ici, vous, barbares et incultes, légers, superbes et arrogants, chez les Italiens si polis et si cultivés, si réfléchis et si modestes, si humains et si bienveillants pour leurs amis et pour leurs ennemis si durs et si terribles, c'est ici, chez nous, que vous voulez habiter? . . . Que sont ces nations d'au delà des Monts qui n'ont aucune connaissance des lettres humaines, ni des latines ni des grecques? Qu'ils s'en aillent avec leurs sophismes, qu'ils s'en aillent ces ignorants des bonnes lettres et de la parole, dont les yeux sont couverts d'obscurité et qui ne voient pas combien cette obscurité est épaisse. C'est ainsi que parlent les Italiens. Ne savent-ils donc pas combien l'Université de Paris est

florissante et ses lettres prospères? C'est ce que reconnaissent eux-mêmes les Italiens sages, doués de science et d'expérience. Cependant ils affirment audacieusement que les lettres grecques nous manquent, et c'est en cela, du moins, qu'ils se glorifient de l'emporter sur les Français. Aujourd'hui s'ouvre le chemin par où nous pourrions leur enlever cette palme des mains. A cette entreprise est promis un facile et prochain succès, si vous le voulez. Travaillons donc de concert. Aidons-nous les uns les autres. Et ainsi, après avoir parcouru les éléments du grec, chacun de vous, par son zèle et son travail augmentera, pour ainsi dire, le Gymnase antique et l'Académie d'Athènes, si bien que les Italiens succomberont facilement dans les lettres grecques et latines, et les céderont enfin aux Français.<sup>13</sup>

By the middle of the sixteenth century Estienne Pasquier had enough confidence in the achievements of the French to prove that they were superior to the Romans in arms and letters; even the old Bards and Druids, from whom stem theology and philosophy, were more advanced in those pursuits than the Romans; indeed, the Romans drew upon them for inspiration.<sup>14</sup> The height of French self-confidence is reached by Du Bellay and Amyot. Du Bellay goes so far as to assert the superiority of the French moderns over the ancients:

... Sommes-nous doncques moindres que les Grecs ou Romains, qui faisons si peu de cas de la nostre? Je n'ay entrepris de faire comparaison de nous à ceux-là, pour ne faire tort à la vertu françoise, le conferant à la vanité gregeoise: et moins à ceux-cy, pour la trop ennuyeuse longueur que ce seroit de repeter l'origine des deux nations, leurs faits, leurs lois, mœurs et manieres de vivre: les consuls, dictateurs et empereurs de l'une, les roys, ducs et princes de l'autre. Je confesse que la fortune leur ait quelquefois esté plus favorable qu'à nous: mais aussy diray-je bien (sans renouveler les vieilles playes de Rome, et de quelle excellence en quel mespris de tout le monde, par ses forces mesmes elle a été precipitée) que la France, soit en repos ou en guerre, est de long intervalle à preferer à l'Italie, serve maintenant et mercenaire de ceux auxquels elle souloit commander. Je ne parleray ici de la temperie de l'air, fertilité de la terre, abondance de tous genres de fruicts necessaires pour l'aise et entretien de la vie humaine, et autres innumerables commodités que le ciel, plus prodigalement que liberalement, a elargy à la France. Je ne conteray tant de grosses rivières, tant de belles forests, tant de villes, non moins opulentes que fortes, et pourveues de toutes munitions de guerre. Finablement je ne parleray de tant de mestiers, arts et sciences qui florissent entre nous, comme la musique, peinture, statuaire, architecture et autres, non gueres moins que jadis entre les Grecs et Romains. Et si pour trouver l'or et l'argent, le fer n'y viole point les sacrées entrailles de nostre antique mere; si les gemmes, les odeurs et autres corruptions de la première generosité des hommes n'y sont point cerchées du marchand avare: aussy le tigre enragé, la cruelle semence des lyons, les herbes empoisonneresses et tant d'autres pestes de la vie humaine, en sont bien éloignées. Je suis content que

<sup>13</sup> Tissard, François, quoted by Hubert Gillot, *La Querelle des anciens & des modernes en France* . . . (Nancy, 1914), pp. 24-25.

<sup>14</sup> Pasquier, Estienne, "Lettre XII. A Monsieur Sebilet, Advocat au Parlement de Paris," *Les Œuvres d'Estienne Pasquier* . . . (Amsterdam, 1723), II: 20.

ces felicités nous soient communes avecques autres nations, principalement l'Italie: mais quant à la piété, religion, integrité de mœurs, magnanimité de courage, et toutes ces vertus rares et antiques (qui est la vraie et solide louange) la France a toujours obtenu, sans controverse, la premier lieu.<sup>15</sup>

Similar citations could be made from the writings of the humanists of other nations, but enough evidence has been shown to indicate that in the Renaissance a strongly motivating force toward the production of works of culture was the desire to bring one's country to the approving notice of the learned of other countries. Moreover, it was not enough to be as good as Italy; one's country must be even better. The emergence of cultural nationalism is thus coincidental with the rise of political nationalism, but in the Renaissance the cultural rivalry remained friendly and coöperative.

It cannot be repeated too often that the Reformation in England was both humanistic and Protestant; learning and religion were made to serve each other, and the loss of one affected adversely the development of the other. It is therefore no wonder that Bale was able to condemn so vigorously the destruction of the monastery libraries. The course of the emergence of cultural nationalism in England was a slow one, and it coincided with the development of the English revival of learning, which may be conveniently divided into three stages.

In the first phase, from about 1450 to about 1520, England was developing a group of humanists who were in direct contact with the leaders of humanistic activity in Italy and who undertook to carry on the Italian humanistic tradition in England. A respectable number of learned men visited in England during this period and, though it is not possible to trace their influence, it is not improbable that they were looked on by those who were already feeling the touch of the new learning as models to be imitated.<sup>16</sup> Then, of course, there were the English scholars who went to Italy and who established a considerable reputation for learning.<sup>17</sup>

<sup>15</sup> Du Bellay, Joachim, *La Défense et Illustration de la langue française*, ed. Louis Humber (Paris, 1930), pp. 111-112.

<sup>16</sup> See Howard L. Gray, "Greek Visitors to England in 1455-56," in *Anniversary Essays in Mediaeval History*, by Students of Charles Homer Haskins, ed. Charles H. Taylor and John L. La Monte (Boston, 1929), pp. 81-116.

<sup>17</sup> See Montagu Burrows, "Memoir of William Grocyn," in *Collectanea*, Second Series (Oxford Historical Society, 1890), pp. 332-378; Ingram Bywater, *Four Centuries of Greek Learning in England* (Oxford, 1919); Mandell Creighton, "The Early Renaissance in England," in *Historical Lectures and Addresses*, ed.

It was during this period that the English developed humanists of a stature great enough to challenge the Italians. Polydore Vergil writes: "Iisdem temporibus perfectae literae similiter Latinae atque Graecae . . . sese trans Alpes effuderunt,"<sup>18</sup> and Aldus Manutius says of Linacre:

. . . And still I hope he will soon publish those and his other most useful works on Physics and Medicine, so that from the same Britain whence formerly a barbarous and unlearned literature made its way to us, occupying and still holding our Italian citadel, we who are now learning to speak in Latin, and as becomes men of learning, shall receive a knowledge of true science, and, having with British aid put barbarism to flight, win back our citadel. We shall thus recover it by the use of the very weapons which caused the disaster.<sup>19</sup>

Duke Humphrey is almost universally spoken of as the initiator of the revival of classical learning in England, and Aeneas Sylvius writes of the Duke as follows:

. . . Congratulor tibi & Angliae: quia iam uerum dicendi ornatum suscepisti. Sed magnae ob hanc causam referendae sunt grates clarissimo illi & doctissimo principi Clocestriae duci, qui studia humanitatis summo studio in regnum uestrum recepit. Qui sicuti mihi relatum est & poetas mirificè colit, & Oratores magnopere ueneratur.<sup>20</sup>

At the same time, others received their share of praise. Jacopo Sadoletto pays his respects to Erasmus for bringing the new learning to England,<sup>21</sup> while George Lily thinks that it was William Groeyn who first introduced the study of Greek and Latin into that country. But the religious, social, and political troubles of the next forty years

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Louise Creighton (London, 1903), pp. 188-212; Lewis D. Einstein, *The Italian Renaissance in England* (Columbia University Press, 1913); Vincent J. Flynn, "Englishmen in Rome during the Renaissance," *Mod. Philol.*, 36 (1938): 121-138; Albert Hyma, "The Continental Origins of English Humanism," *Huntington Lib. Quart.*, 4 (1940): 1-25; H. Maynard Smith, *Pre-Reformation England* (London, 1938); George R. Stephens, *The Knowledge of Greek in England in the Middle Ages* (Philadelphia, 1933); Arthur Tilley, "Greek Studies in England in the Early Sixteenth Century," *Eng. Hist. Rev.*, 53 (1938): 221-239, 428-456; Elizabeth Cox Wright, "Continuity in XV Century English Humanism," *Publ. Mod. Lang. Assn.*, 51 (1936): 373-376.

<sup>18</sup> Quoted by Gray, *op. cit.*, p. 102.

<sup>19</sup> Manutius, Aldus, Preface to Linacre's *Sphere of Proclus*, October 14, 1499, quoted by Burrows, *op. cit.*, p. 350.

<sup>20</sup> Sylvius, Aeneas, to Adam de Molin, No. 64, *op. cit.*, p. 548.

<sup>21</sup> Sadoletto, Jacopo, to Henry VIII, July 10, 1515, *Epistolae* . . . (Rome, 1759), p. 127. Cf. Hoyt H. Hudson, "John Leland's List of Early English Humanists," *Huntington Lib. Quart.*, 2 (1939): 301-304.

interfered with the normal development of humanistic studies in England, and the conditions which Hales described prevailed; this is the second phase.

When, in the third phase, learning reëmerged after the accession of Elizabeth to the throne, it was something different from what it had been in the first phase, for it had passed through the pressures of the Reformation and English nationalism. Scholarship was still considered a good in itself but, more than that, it had become useful; it had become part of the equipment of the English gentleman. Most important of all, it had become the substratum out of which English literature developed; its direction was reoriented in terms of imaginative composition. As a consequence, the English felt it was no longer necessary to go to Italy for learning. We find Sidney writing:

. . . As for Italy, I knowe not what wee have or can have to doe with them, but to buy their silks and wines; and for the other provinces, excepting Venice, whose good lawes and customes wee can hardly proportion to ourselves, because they are quite of a contrary government; there is little there but tyrannous oppression, and servile yielding to them that have little or noe rule over them; and for the men, you shall haunt them, although some indeed be excellently learned, yett are they all given to love counterfeit learning, as a man shall learne of them more false grounds of things then in any place else I do know . . . .<sup>22</sup>

To such a low state had Italian scholarship fallen. Daniel goes even beyond Sidney:

O that the Ocean did not bound our stile  
Within these strict and narrow limites so:  
But that the melodie of our sweete Ile,  
Might now be heard to *Tyber*, *Arne* and *Po*:  
That they might know how far Thames doth out-go  
The Musike of declined *Italy*:  
And listning to our Songs another while,  
Might learne of thee, their notes to purifie.

O why may not some after-comming hand  
Vnlocke these limites, open our confines,  
And breake asunder this imprisoning band,  
T'inlarge our spirits, and publish our designes;  
Planting our Roses on the *Apenines*?  
And teach to *Rheyne*, to *Loyre*, and *Rhodanus*  
Our accents, and the wonders of our Land,  
That they might all admire and honour vs.

<sup>22</sup> "A Letter Written by Sir Phillip Sidney, to a Brother of His, Touching the Direction of His Travayle. MS.," in *Somers Tracts*, ed. Walter Scott (London, 1809), I: 496.

Whereby great *Sydney* and our *Spencer* might,  
 With those *Po-singers* being equalled,  
 Enchaunt the world with such a sweet delight,  
 That their eternall Songs (for euer read)  
 May shew what great *Elizass* reigne hath bred.  
 What musicke in the kingdome of her peace  
 Hath now beene made to her, and by her might,  
 Whereby her glorious fame shall neuer cease.<sup>23</sup>

According to Harvey, all learning has left Europe to come to England:

. . . It is not long, since the goodliest graces of the most-noble Commonwealthes vpon Earth, Eloquence in speech, and Ciuility in manners, arriued in these remote parts of the world: it was a happy reuolution of the heauens, and worthy to be chronicled in an English Liuy, when Tiberis flowed into the Thames; Athens remoued to London; pure Italy, and fine Greece planted themselves in rich England; Apollo with his delicate troupe of Muses, forsooke his old mountaines, and riuers; and frequented a new Parnassus, and an other Helicon, nothinge inferiour to the olde, when they were most solemnely haunted of diuine wittes, that taught Rhetorique to speake with applause, and Poetry to sing with admiration. But euen since that flourishing transplantation of the daintiest, and sweetest lerning, that humanitie euer tasted; Arte did but springe in such, as Sir Iohn Cheeke, and M. Ascham: & witt budd in such, as Sir Phillip Sidney, & M. Spencer, which were but the violetes of March, or the Primeroses of May. . . .<sup>24</sup>

As a result of the feeling that England was now the home of the Muses, the past was studied in an attempt to establish the truth of the assertion that England had been preëminent in culture even before the continental nations, and that it had not been necessary to turn to others for inspiration. This led to the discovery of Chaucer, who was held to be the father of English poetry, though Erasmus thought that Skelton had taught the Muses to speak English words instead of Latin. The Renaissance attitude toward the Middle Ages is composed of two divergent factors. On the negative side, the Renaissance criticized the Middle Ages not so much because it had no art and learning but, rather, because it did not have the right kind — in Renaissance eyes, that is — of art and learning. But if the Renais-

<sup>23</sup> Daniel, Samuel, "To the Comtesse of Pembroke," *The Tragedies of Cleopatra, in The Complete Works in Verse and Prose of Samuel Daniel*, ed. Alexander B. Grosart (London, 1885), III: 26-27.

<sup>24</sup> Harvey, Gabriel, *Pierces Supererogation or a New Prayse of the Old Asse*, in *The Works of Gabriel Harvey*, ed. Alexander B. Grosart (London, 1884-85), II: 49-50. Cf. Thomas Edwards, "To the Honorable Gentlemen & true fauourites of Poetrie," *Cephalus and Procris. Narcissus*, ed. W. E. Buckley (London, 1882), p. 4.



sance was the first to disparage the Middle Ages, it was also the first to appreciate them. Here at this point the emergence of cultural nationalism ties in with the development of the appreciation of the Middle Ages, for once one begins to praise the contemporary culture of his native land, it is but a natural step to assert: first, that it is indigenous and uninfluenced by foreign lands; secondly, that it stems from a native tradition; and, thirdly, that this native tradition is even older than that of other lands.<sup>25</sup> In any case, a native English tradition of good letters was insisted on and became an important part of the cultural nationalism which swept over England.<sup>26</sup>

The sixteenth-century Englishman's attitude toward his native land is summed up by George Best:

By this Discourse, it may please your Honour to behold the greate industrie of oure present age, and the inuincible mindes of our Englishe nation, who haue neuer left anye worthy thing vnattempted, nor anye part almoste of the whole world vnsearched, whome lately, neyther stormes of Seas by long and tedious voyages, danger of darke fogs and hidden rockes in vuknown coastes, congealed and frozen Seas, with mountaines of fleeting Ice, nor yet present death dayly before their face, coulede any white dismay, or cause to desiste from intended enterprises: but rather preferring an honourable death before a shameful retourne, haue (notwithstanding the former daungers,) after many perillous repulses recovered their desired Port. So that if now the passage to CATAYA thereby be made open vnto vs, (which only matter hytherto hath occupied the finest heades of the world, and promiseth vs a more riches by a nearer way then eyther Spaine or Portugale possesseth) whereof the hope (by the good industrie and great attemptes of these men is greatly augmented) or if the Golde Ore in these newe Discoueries founde out, doe in goodness, as in greate plentie aunswere expectation, and the successe do folow as good, as the prooffe thereof hitherto made, is great, we may truely infer, that the Englishman in these our dayes, in his notable discoueries, to the Spaniard and Portingale is nothing inferior: and for his hard adventures, and valiant resolutions, greatly superior. For what hath the Spaniarde or Portingale done by the Southeast and Southweast, that the Englishman by the Northeast and Northweaste hath not counteruailed the same?<sup>27</sup>

So strong is the force of his patriotism that Best's prose soars to lyrical heights and is better than a good deal of the verse written on

<sup>25</sup> I have discussed these matters in an article called "The Renaissance Attitude toward the Middle Ages," forthcoming in *Speculum*.

<sup>26</sup> Cf. Hans Kohn, "The Genesis and Character of English Nationalism," *Journal of the History of Ideas*, 1 (1940): 69-94; Hans Kohn, *The Idea of Nationalism* (New York, 1944); Ruth Wainwright, "Nationalism in the Literature of the English Renaissance," *Vassar Journal of Undergraduate Studies*, 6 (1932): 108-149.

<sup>27</sup> Best, George, *The Three Voyages of Martin Frobisher . . . from the Original 1578 Text of George Best*, ed. Vilhjalmur Stefansson and Eloise McCaskill (London, 1938), I: 6-7.

the same subject.<sup>28</sup> It was in Elizabeth's reign that the tradition was built up that the Elizabethan Age was the golden age of English literature. In this the English acted as did the men of other nations during the same period.

What is the significance of the material presented here? The primacy of Petrarch, Dante, and Boccaccio in initiating the revival of learning is a fact which is known to almost all and hence is seemingly hardly worth repeating. But that is exactly the point which is so intriguing to the historian of ideas. For this very concept is one for which the men of the Renaissance are themselves responsible. They were the first to state the concept for later generations, including ourselves, to accept and to repeat. We have taken at face value the words of the men who would be most likely to wish to convince others that what they were doing was something new and worth while, but such affirmation is by no means a guarantee that they had in fact accomplished any such ends. The awareness of this fact has resulted in the suspicion evidenced in the work of a number of recent scholars who have attempted to show, with some success, that the Renaissance as we ordinarily conceive of it did not take place at the time usually set for it, nor was it begun by the men usually thought to be responsible for it, and, in short, the entire concept of the Renaissance has been challenged and even denied.

Without entering into the controversy whether or not there actually was a Renaissance, I should like to suggest that the intense self-awareness of the Renaissance is a real historical phenomenon which affords a satisfactory criterion for the identification of the Renaissance. The consciousness of one's place in history is one of the peculiar marks of the modern temper; and it is seen most clearly in the Renaissance, from which it was originally derived. Conversely, there is hardly any such consciousness in the Middle Ages; the sense of historicity, of being unique and different from preceding ages, is notably absent. The Middle Ages seemed to think that by and large men at all times have been pretty much the same; history is

<sup>28</sup> Cf. Roger Portington, "In Commendation of this Booke," in *Mamillia, in The Life and Complete Works in Prose and Verse of Robert Greene*, ed. Alexander B. Grosart (London, 1881-86), II: 11-12; Maurice Kyffin, "The Blessedness of Brytaine," in *Fugitive Tracts Written in Verse*, ed. W. C. Hazlitt (London, 1875), I, n.p.; Fulke-Greville, "A Treatise of Monarchy. Of Commerce," in *The Works in Verse and Prose Complete of the Right Honourable Fulke Greville, Lord Brooke* (London, 1870), I: 148.

not developmental but moral. The Renaissance, with its strong conviction of difference from the Middle Ages, strikes a genuine modern note, for it is aware of itself in its own unique character. The discovery of historical self-awareness, which is both a blessing and a curse, is the great contribution of the Renaissance to the evolution of the Western mind.

MICHIGAN STATE COLLEGE  
EAST LANSING, MICHIGAN

# "WHY NATURE LOVES THE NUMBER FIVE"

## EMERSON TOYS WITH THE OCCULT

MENTOR L. WILLIAMS

### I

TO THE second number of *The Dial*,<sup>1</sup> transcendental repository of Yankee-Orphic wisdom, Emerson contributed "Woodnotes, I," a poem over which there has been much altercation. But, in their argument about the identity of the "forest seer," scholars have neglected to observe that this poem, as well as its successor, "Woodnotes, II," is filled with provocative problems. It is my intention in this paper to examine one of those problems, hoping thereby to throw light on some aspects of Emerson's mysticism.

The poet, said Emerson in this poem, walks in the woodland with God-enchanted eye, yet

What he knows nobody wants.

.....

Knowledge this man prizes best

Seems fantastic to the rest:

Pondering shadows, colors, clouds,

Grass-buds and caterpillar-shrouds,

.....

Why Nature loves the number five,

And why the star-form she repeats<sup>2</sup>. . .

Edward Emerson annotated the last two lines with a passage from the *Journals* which, though it did not explain the mystery, indicated that the idea had long been in Emerson's mind. The poem was written in 1840; the entry in the *Journals* was dated May 14, 1835. The passage reads as follows:

. . . Trifles move us more than laws. Why am I more curious to know the reason why the star form is so oft repeated in botany, why the number five is

<sup>1</sup> October, 1840. The second part of "Woodnotes" was published a year later, in *The Dial*, October, 1841.

<sup>2</sup> *The Complete Works of Ralph Waldo Emerson*, ed. Edward Waldo Emerson, 12 vols. (Boston: Houghton Mifflin Co., 1903-4), IX: 43-44. Hereafter this edition will be referred to as *Works*.

such a favorite with Nature, than to understand the circulation of the sap and the formation of buds? Those two wonders of electro-magnetism and the polarization of light have also a peculiar interest.<sup>3</sup>

The concept of number in nature reappeared in the 1840 essay, "Nature," where Emerson remarked: "A man does not tie his shoe without recognizing laws which bind the farthest regions of nature: moon, plant, gas, crystal, are concrete geometry and numbers."<sup>4</sup> This is but one of many references to the fact of number as a key to nature's organization. But we still are ignorant of the source of this concept.<sup>5</sup>

Professor Howard M. Jones, in an editorial footnote to the verses quoted, offers a positive explanation:

. . . This refers to the doctrine known as quinarianism, a fanciful classification of organic forms on the hypothesis that they dispose themselves in sets of five. It was largely advocated by William Swainson (1789-1855), British naturalist.<sup>6</sup>

Professor Jones' explanation is an excellent one save for the fact that nowhere in all of Emerson is there mention either of quinarianism or of Swainson or MacLeay or Adam or Decandolle or Fries or Kirby or Lindley, all of whom were professors of the quinary theory between 1800 and 1840.<sup>7</sup> That Emerson may have heard of them is not unlikely because their theories of classification were widely published in the transactions of the various natural-history societies. Nevertheless, there is no first-hand evidence that he had read them.

The answer to this puzzling problem can more probably be discovered in certain obvious sources recorded in the *Journals* and the *Letters*. When one considers the nature of Emerson's curiosity about natural facts, especially about the esoteric and mystic phases

<sup>3</sup> *The Journals of Ralph Waldo Emerson*, ed. Edward Waldo Emerson and Waldo Emerson Forbes, 10 vols. (Boston: Houghton Mifflin Co., 1909-14), III: 482. Hereafter this edition will be referred to as *Journals*.

<sup>4</sup> *Works*, III: 183.

<sup>5</sup> Oliver Wendell Holmes, commenting on the line in "Woodnotes," does no more than say, "Emerson wonders . . . but leaves his note of interrogation without troubling himself any farther." *The Complete Works of Oliver Wendell Holmes*, 13 vols. (Boston: Houghton Mifflin Co., 1892), XI: 311. Holmes, however, was much in error.

<sup>6</sup> Jones, Howard M., and Leisy, Ernest, *Major American Writers* (New York: Harcourt, Brace and Co., 1936), p. 363.

<sup>7</sup> See Rees' *Cyclopaedia* (London, 1819), article "Classification," Vol. VIII.

of those facts, it is only logical that one investigate whether he was acquainted with the two most numerological minds of all time: Pythagoras, the father of numerology, and Sir Thomas Browne, collector of all the quincuncial evidences in the natural universe.

Pythagoreanism implanted two ideas in the western mind, the doctrine of the transmigration of souls<sup>8</sup> and the theory that the universe is Number. Every collegian of the early nineteenth century was familiar with the system of Pythagorean numbers: 1 for the point, 2 for the line, 3 for the plane, 4 for the tetrahedron, 5 for physical quality, 6 for animation, 7 for love or wisdom, etc. Some Pythagoreans said 4 was justice; others insisted on 9. The number 5 generally stood for marriage; 2 was feminine and 3 was masculine, therefore 5 represented union. Even numbers were unlimited and indeterminate; odd numbers were limited and definite.<sup>9</sup>

In the *Journals* for 1830 Emerson recorded at length his reading in Baron de Gérando's *Comparative History of Philosophical Systems*. Among other philosophical items there appear extensive digests of Pythagorean ideas, including the following:

... Pythagoras taught that Numbers were the principles of things; the monad, one, eternal, simple, perfect; the dyad imperfect, matter, chaos.

Beings are bound together by a chain of relations parallel or like to those which unite numbers. All these relations converge to one centre. World forms one whole. Symmetry presides over the systems of their dependence and their connexion.<sup>10</sup>

The lists of Emerson's readings for 1832 and 1839 included Pythagoras. Subsequently he read the *Pythagorean Fragments* and Iamblichus' *Life of Pythagoras*,<sup>11</sup> both translated by Thomas Taylor, the English Neo-Platonist of the Romantic Movement.

More important than Pythagorean influence is the evidence pointing to Sir Thomas Browne as a source for the "quinarian"

<sup>8</sup> Emerson was much concerned with this concept of metempsychosis. See F. I. Carpenter, *Emerson and Asia* (Cambridge: Harvard University Press, 1930), pp. 134 ff.

<sup>9</sup> For discussions of Pythagorean "numerology" see E. T. Bell, *Numerology* (Baltimore: Williams and Wilkins Co., 1933); Leon Robin, *Greek Thought and the Origins of the Scientific Spirit* (New York: Alfred A. Knopf, 1928); W. T. Stace, *A Critical History of Greek Philosophy* (London: Macmillan, 1924); B. A. G. Fuller, *History of Greek Philosophy* (New York: Henry Holt and Co., 1928).

<sup>10</sup> *Journals*, II: 340.

<sup>11</sup> *Journals*, Vols. V, VI, *passim*. Emerson may also have known Thomas Taylor's *Theoretical Arithmetic* (London, 1816), a volume in which the Pythagorean number philosophy was developed. See particularly Book III.

statement. In 1838-39 Emerson delivered a series of lectures to audiences in Boston and repeated them in the early months of 1839 in Concord. Probably because his last lecture of the series had dealt with the popular subject of demonology, the grateful citizens of Concord thought a set of Browne's works would be a suitable gift for the young lecturer.<sup>12</sup> To Margaret Fuller, Emerson wrote, July 9, 1839: "I have also archaic Sir Thomas Browne, correspondence, Vulgar Errors, & All, in which I have read a little."<sup>13</sup> This refers undoubtedly to the four-volume edition prepared by Simon Wilkin in 1835.<sup>14</sup> Volume III of this work contains "The Garden of Cyrus, or the Quincuncial Lozenge, or Net-work Plantations of the Ancients, Artificially, Naturally, Mystically Considered." As this essay was sandwiched between "Vulgar Errors" and "Urn Burial," both of which Emerson referred to frequently, it is highly unlikely that he overlooked this unique contribution to esoteric and mystic lore. In the editor's "Preface" reference was made to Coleridge's famous remark: "Quincunxes in heaven above, quincunxes in earth below, quincunxes in the mind of man, quincunxes in tones, in optic nerves, in roots of trees, in leaves, in everything."<sup>15</sup> The editor also called attention to current quinarism:

. . . The increased attention, however, which modern naturalists have paid to the prevalence of certain numbers in the distribution of nature, and Mr. Macleay's persevering and successful advocacy of a QUINARY ARRANGEMENT would naturally lead an admirer of Browne to look at this work in a higher point of view than as a mere *jeu d'esprit*.<sup>16</sup>

Footnotes on the contemporary quinarian doctrines as applied to biological classification were provided by E. W. Brayley in the appropriate places.<sup>17</sup> Emerson, of course, was aware of Browne's work before the citizens of Concord gave him this edition. He had quoted passages from "Hydriotaphia" in his *Journals* as early as 1830,<sup>18</sup> and the reading lists show that Browne was one of the standard entries.

<sup>12</sup> *The Letters of Ralph Waldo Emerson*, ed. Ralph L. Rusk, 6 vols. (New York: Columbia University Press, 1939), II: 207-208. Hereafter this edition will be referred to as *Letters*. <sup>13</sup> *Letters*, II: 209.

<sup>14</sup> Wilkin, Simon, F.L.S. (ed.), *Sir Thomas Browne's Works Including His Life and Correspondence*, 4 vols. (London: William Pickering, 1835).

<sup>15</sup> *Ibid.*, III: 380.

<sup>16</sup> *Ibid.*

<sup>17</sup> *Ibid.*, III: 413, 423, 439, 446.

<sup>18</sup> *Journals*, II: 327. See also the entry for November 25, 1838, on Browne's "inwardness." *Journals*, V: 146.

Of course, Emerson, as a Latin scholar, may have noticed references to the quincunx in Cicero's *De Senectute*, 17, 59; in Caesar's *De Bello Gallico*, 7, 73, 5;

At least twice Emerson employed the word "quincunx." On October 31, 1836, the day following the birth of his first child, he recorded in his journal:

. . . The world is full of happy marriages of faculty to object, of means to end; and all of Man marries all of Nature, and makes it fruitful. Man may be read, therefore, if you choose, in a history of the Arts, or in a history of the Sciences. Every tendency in him writes itself out somewhere to its last effort. He is a quincunx, and may be read forward, backward, or across.<sup>19</sup>

When one notes that in Emerson's own thinking Lidian Emerson, "Mine Asia," was symbolic of his other half, the feminine principle in Man, the opposite pole in Nature,<sup>20</sup> it is not strange that he should have chosen the quincunx, the Pythagorean number five signifying marriage or union, for the entry just cited. Again in the essay "Spiritual Laws" (1841) Emerson made the same association of five with the union of physical qualities.

. . . Every quality of [man's] mind is magnified in some one acquaintance, and every emotion of his heart in some one. He is like a quincunx of trees . . . . And why not? He cleaves to one person and avoids another, according to their likeness or unlikeness to himself, truly seeking himself in his associates and moreover in his trade and habits and gestures and meats and drinks . . . .<sup>21</sup>

## II

Of what significance is this excursus into the origin of Emerson's observation that Nature loves the number five? It focuses our attention clearly on one aspect of the attempt of the intellectual mind to cope with the problems of the new freedom and the new knowledge — the acceptance of mystic, occult aids.

For the past three centuries science and learning had been adding vast quantities of particulars to the total store of man's knowledge. The result was overwhelming. Amid all this variety, manifoldness, and multiplicity there must be some unifying principle, some law that would bring a sane order out of confused, chaotic variety. Everywhere, in the late eighteenth and early nineteenth centuries, one discovers a frantic search for a harmonious universe, a

in Varro's *Res Rusticae*, 1, 7, 2. See also Quintilian, *Institutio Oratoria*, 8, 3, 9: "Quid illo quincunce speciosus qui, in quamcunque partem spectaveris, rectus est?" I am indebted to Dr. Eugene S. McCartney, editor of University Publications, for these references to Latin sources.

<sup>19</sup> *Journals*, IV: 136.

<sup>20</sup> Carpenter, *op. cit.*, pp. 30-31.

<sup>21</sup> *Works*, II: 148.



formula to reduce chaos to order. On every hand the seekers were looking for evidence of purposiveness, of creative intelligence. In no area was this agitation more observable than in the field of natural history, especially in biology. There the activity took the form of a series of great debates over principles of classification. There were two world views of organic nature: the morphological and the genetic.

... In the perpetual variety of change the morphological view tries to define these recurring forms or types which present themselves again and again, towards which all changes seem to revert; thus bringing some order into what would otherwise be disorder and confusion. On the other side, the genetic view deals with the transition from one form to another in the course of time; takes more interest in movement and in the process and function; and seeks their probable laws and regularities.<sup>23</sup>

Morphology — the study of developed forms — naturally preceded genetics, the study of developing forms. Linnean classification, based on the morphological character of stamens and pistils, was the first great step in the direction of *natural* classification; a form of classification which considered all resemblances as part of the whole. Then followed the plans of Jussieu and Cuvier, basically morphological, and of Lamarck and Saint Hilaire, primarily genetic, but all elaborately natural. Cuvier, in the introduction to *Fossil Remains*, declared:

... Every organized being forms an entire system of its own, all the parts of which mutually correspond, and concur to produce a certain definite purpose by reciprocal reaction, or by combining to the same end. Hence none of these separate parts can change their forms without a corresponding change in other parts of the same animal; and consequently each of these parts, taken separately, indicates all the other parts to which it has belonged.<sup>24</sup>

This is unquestionably teleological and archetypal biology, biology that was discovering nature's plan — simple and integrated, that is, biology that was thinking God's thoughts.<sup>24</sup> New ideas began to

<sup>23</sup> Merz, J. T., *The History of European Thought in the Nineteenth Century*, 4 vols. (Edinburgh and London, 1896-1914), II: 213-214.

<sup>24</sup> Quoted in William Whewell, *History of the Inductive Sciences*, 2 vols. (New York: D. Appleton and Co., 1858), II: 493. This is the third edition.

<sup>24</sup> This is well illustrated in Whewell's own words: "The real philosopher, who knows that all the kinds of truth are intimately connected, . . . will be satisfied and confirmed, rather than surprised and disturbed, thus to find the Natural Sciences leading him to the borders of a higher region. To him it will appear natural and reasonable, that after journeying so long among the beautiful and orderly laws by which the universe is governed, we find ourselves at last ap-

charge the scientific atmosphere, the doctrine of symmetry, the idea of the coördination and adaptation of parts, notions of correspondence or homology within species, concepts of analogy and affinity. These phrases appear everywhere in the literature of the period.<sup>25</sup>

The overzealous, those who wanted to reduce variety to an ultimate simple unity, turned fanciful and pretended to see natural harmonies, correspondences, analogies, and affinities where none existed. To such activity can be attributed the notion of circular progression, based on the occult idea of the circle as the perfect form. The advocates of circular progression opposed linear progression, or "the ladder of development," because of the saltuses and hiatuses that appeared therein.<sup>26</sup> To such zealotry, also, the doctrine of quinarianism was due.<sup>27</sup> Both doctrines go back to Plotinian, Platonic, and Pythagorean sources. Out of the same habits of thought rose the theory of *metamorphosis* advanced by the *Naturphilosophen* at the turn of the century.<sup>28</sup> Kant, Goethe, Oken, and Spix developed the idea that the parts of a plant are merely modified leaves, that is, the leaves, bracts, sepals, petals, stamens, anthers, styles, and stigmas have a single origin and are different by reason of metamorphosis; that the skull of the vertebrate was formed through the modification of several of the vertebrae. Saint Hilaire carried the Kantian biology still farther in his famous "theory of analogies" when he suggested that there was a close analogy be-  
proaching to a Source of order and law and intellectual beauty . . . " *Ibid.*, II: 495.

<sup>25</sup> The present author hopes in a subsequent article to show that Emerson's "evolutionary" thought was far more in accord with the teleological, Platonic biology of the period than it was with the genetic, naturalistic evolutionism of the middle century.

<sup>26</sup> This fits, of course, the concept expressed in the lines in Emerson's "Uriel,"

"Line in Nature is not found;

Unit and universe are round" (*Works*, IX: 14);

with the general tone of the essay "Circles" (*Works*, II: 301-322); and with the passage in the essay entitled "Swedenborg" (*Works*, IV: 110).

<sup>27</sup> W. S. MacLeay, the best representative of quinarian views, wrote: "We may all possibly be wrong in part, . . . but however this may be, it is difficult not to believe that we are grasping at some great truth, which a short lapse of time will perhaps develop in all its beauty, and at length place in the possession of every observer of nature." "Remarks on the Identity of certain general Laws which have lately been observed to regulate the natural Distribution of Insects and Fungi," *Transactions of the Linnean Society*, 14 (1825): 63.

<sup>28</sup> For a discussion of "Naturphilosophie" see Charles Singer, *A Short History of Science* (Oxford: Oxford University Press, 1941), pp. 332-336.

tween the shells of insects and crustaceans and the skeletons of the higher animals. Thus the segments of the articulates are analogous to the vertebrae of the vertebrates; the former live inside their vertebral column; the latter live outside it.<sup>20</sup>

Emerson was caught up in this intellectual whirlpool. When, in 1833, he visited the Garden of Plants in Paris, he was struck by the affinities between animated forms:

. . . Not a form so grotesque, so savage, nor so beautiful but is an expression of some property inherent in man the observer, — an occult relation between the very scorpions and man. I feel the centipede in me, — cayman, carp, eagle, and fox. I am moved by strange sympathies; I say continually "I will be a naturalist." <sup>21</sup>

On May 3, 1834, Emerson wrote two long passages on the subject of classification which show that he was, with Kant, Goethe, and Coleridge, seeking the answer to unity amid manifoldness in the Platonic and mystic realms.

The Idea according to which the Universe is made is wholly wanting to us; is it not? Yet it may or will be found to be constructed on as harmonious and perfect a thought, self-explaining, as a problem in geometry. The classification of all natural science is arbitrary, I believe; no method philosophical in any one. And yet in all the permutations and combinations supposable, might not a cabinet of shells or a Flora be thrown into one which should flash on us the very thought? . . . All our classifications are introductory and very convenient, but must be looked on as temporary, and the eye always watching for the glimmering of that pure, plastic Idea . . . .

This was what Goethe sought in his *Metamorphosis of plants*. The Pythagorean doctrine of transmigration is an Idea; the Swedenborgian of Affections Clothed, is one also . . . . We have no theory of animated nature. When we have, it will be itself the true Classification. Perhaps a study of the cattle on the mountain-side as they graze is more suggestive of truth than the inspection of their parts in the dissection-room. The way they classify is by counting stamens, or filaments, or teeth and hoofs and shells. A true argument, what we call the unfolding an idea, as is continually done in Plato's *Dialogues*, in Carlyle's *Characteristics*, or in a thousand acknowledged applications of familiar ethical truths, — these are natural classifications containing their own reason in themselves, and making known facts continually. They are themselves the formula, the largest generalization of the facts, and if thousands on thousands more should be discovered, this idea hath predicted already their place and fate. When shall such a classification be obtained in botany? This is evidently what Goethe aimed to do, in seeking the arch-plant, which, being known, would give, not only all actual, but all possible vegetable forms . . . .

Mr. Coleridge has written well on this matter of Theory in his *Friend*. A lecture may be given upon insects or plants, that, when it is closed, irresistibly

<sup>20</sup> Whewell, *op. cit.*, II: 477, 480. Cf. Emerson, *Works*, VIII: 8.

<sup>21</sup> *Journals*, III: 163.

suggests the question, "Well, what of that?" . . . The true classification will not present itself to us in a catalogue of a hundred classes, but as an idea of which the flying wasp and the grazing ox are developments. Natural History is to be studied, not with any pretension that its theory is attained, that its classification is permanent, but merely as full of tendency.<sup>21</sup>

Natural history is to be studied as "full of tendency." While these views certainly led him, as Professor Clark and others have clearly pointed out,<sup>22</sup> to accept and foster the theory of evolution, it is equally clear that Emerson's concept of science belongs in part to the realm of the occult. By flashes, by revelation, by blinding bursts of insight he comes to know the meaning of the natural world. In the essay "The Poet" he declares: "The poet alone knows astronomy, chemistry, vegetation and animation, for he does not stop at these facts, but employs them as signs."<sup>23</sup> Again, in a lecture entitled "Poetry and Imagination," Emerson asserts:

. . . The poet is a better logician than the anatomist. . . . He sees the fact as an inevitable step in the path of the Creator. . . . Never did any science originate but by a poetic perception. . . . For a wise surrender to the current of Nature, a noble passion which will not let us halt, but hurries us into the stream of things, makes us truly know. Passion is logical, and I note that the vine, symbol of Bacchus, which intoxicates the world, is the most geometrical of plants.<sup>24</sup>

It is only the poet-scientist who would turn to the occult for his explanations. Through symbols, emblems, and talismans, through dreams, clairvoyant and trance states, through daemons and transmigration of souls, through the love of riddles and gnomic verse, the language of Emerson is patently on the side of the occult.<sup>25</sup> His earnest enthusiasms for Swedenborg, Behmen, Jones Very, and others who somehow penetrated the innermost arcana show him, denied the phantom power himself, content to rely on the mysteries revealed to others, hoping faithfully that the same answers would some day be granted him by the same abracadabra. More interesting, did space permit, would be an exposition of his reliance upon

<sup>21</sup> *Journals*, III: 292-296. Additional evidence of Emerson's linking the secrets of nature with Platonic views can be found in "Nature" (*Works*, III: 169-196) and "Swedenborg" (*Works*, IV: 93-146).

<sup>22</sup> See especially H. H. Clark, "Emerson and Science," *Philological Quarterly*, X (1931): 225-260.

<sup>23</sup> *Works*, III: 21. See also "Poetry and Imagination," *Works*, VIII: 3-75.

<sup>24</sup> *Works*, IX: 445.

<sup>25</sup> See the Index to the *Complete Works* for the large numbers of entries under these categories. The index, however, is incomplete.

the Orphic concepts of early Greek religionists, on the hermetic doctrines contained in *Hermes Trismegistus*, on the fantastic myths of the *Chaldean Oracles*.<sup>36</sup> His mind was naturally attuned to this type of esoteric knowledge. "The deepest pleasure," he wrote, "comes . . . from the occult belief that an unknown meaning and consequence work in the common, every-day facts, and, as a panoramic or pictorial beauty can arise from it, so can a solid wisdom, when the Idea shall be seen as such which binds these gay shadows together."<sup>37</sup> Without doubt he spurned spiritual quackery — "We must check this low curiosity,"<sup>38</sup> "Mesmerism is high life below stairs," "Animal magnetism peeps"<sup>39</sup> — yet he accepted these pseudosciences as lesser aspects of his own mystic world.

. . . How slowly, how slowly we learn that witchcraft and ghostcraft, palmistry and magic and all the other scattered superstitions, which, with so much police, boastful skepticism and scientific committees, we had finally dismissed to the moon as nonsense, are really no nonsense at all but subtle and valid influences . . . The things are real, only they have shed their skin, which with much insult we have gibbeted and buried.<sup>40</sup>

. . . Anomalous facts, as the never quite obsolete rumors of magic and demonology, and the new allegations of phrenologists and neurologists, are of ideal use. They are good indications.<sup>41</sup>

There is a demonstrable tendency, then, as the line "Why Nature loves the number five" reveals, for Emerson to resort to intangible or vague mysteries, to the primitive concepts of the ancients, to the language of symbolic myths, to the "divine visual language" of nature which characterized many Neo-Platonic "visions." These things have the virtue of an Aladdin's lamp; evoke the genie and the mystery of the universe will be made clear. He understood well enough the higher mystical experience — the attainment of truth or reality or divine essence through immediate insight or revelation. He could describe it and explain it; yet in his own experience he was limited to the lower plane of mysticism, to the occult representations of ancient fable and to the occult metaphor of those earliest philosophers on the harmonies of nature. He never ceased to hope for and look for a magic formula by which "the laws of moral nature answer to those of matter as face to face

<sup>36</sup> This is clearly a subject for an extended study.

<sup>37</sup> *Journals*, IV: 100.

<sup>38</sup> *Works*, II: 283.

<sup>39</sup> Both quotations appear in *Works*, X: 25.

<sup>40</sup> *Journals*, VI: 245.

<sup>41</sup> *Works*, III: 234.

in a glass." Always there sat the "Sphinx at the roadside," a riddle to be read. He was reduced, in his explanation of the spirit-matter, each-all, unity-variety phenomena, to such phrasings as "the axioms of physics translate the laws of ethics"<sup>42</sup> or "see the identity of the law of gravitation with purity of heart."<sup>43</sup> These scarcely rise above a simple extension of the Pythagorean theory of numbers.<sup>44</sup> Truly,

Knowledge this man prizes best  
Seems fantastic to the rest.

UNIVERSITY OF MICHIGAN

<sup>42</sup> *Works*, I: 33-34.

<sup>43</sup> *Works*, I: 151.

<sup>44</sup> Compare also with the medieval doctrine of "signatures."



# **MEDICAL SCIENCE**





## THE EFFECT OF DIODOTYROSINE ON THYROIDECTOMIZED RATS GIVEN A SINGLE DOSE OF THYROXIN \*

SALLY A. EDWARDS AND GEORGE R. SHARPLESS

IN RECENT years much work has been done on the effect of various substances on the thyroid gland and its hormone. Included in those tested were the sulfonamides, possibly because of their wide use as chemotherapeutic agents in the treatment of various bacterial infections. A number of workers, among them MacKenzie and MacKenzie (5), Astwood and his coworkers (2), and Sharpless (10) have found that sulfaguanidine produces a definite thyroid hyperplasia in rats. The goiter thus formed differs from other experimental goiters in that it is not associated with simple iodine deficiency, since iodine alone will not prevent its formation. Although MacKenzie and MacKenzie have noted that sulfaguanidine may lower the metabolic rate as well as produce thyroid hyperplasia in an intact animal, this effect is apparently due to action on the gland itself rather than on the circulating hormone. In thyroidectomized rats previously given thyroxin, treatment with the drug had no effect on the metabolic rate. Furthermore, it has been noted by Franklin and Chaikoff (4), in radioiodine studies, that sulfanilamide, a compound closely related to sulfaguanidine, inhibits the synthesis of diiodotyrosine and thyroxin by thyroid tissue in vitro, the degree of inhibition being directly proportional to the drug concentration.

In order to determine how goiter formation might be controlled various substances were fed with sulfaguanidine (10). An addition of desiccated thyroid prevented goiter formation. Supplements of inorganic iodine decreased the size of the goiter somewhat. It was felt that the beneficial effect of iodine might be enhanced if it was given in the organic form. Accordingly, diiodotyrosine was added to the sulfaguanidine diet in an amount equivalent in iodine content

\* From the Department of Laboratories, Henry Ford Hospital, Detroit, Michigan.

to the inorganic iodine previously given. Instead of goiter inhibition equal or superior to that of the inorganic iodine, this treatment produced a larger goiter.

Since the theory has been rather widely accepted that diiodotyrosine is an intermediate compound in the synthesis of thyroxine from inorganic iodine, this result was surprising. In the search for an explanation of this unusual result a series of experiments was devised in order to determine whether or not diiodotyrosine had any effect on the metabolic rate. A group of thyroidectomized rats were fed a supplement of diiodotyrosine with the stock diet, but no appreciable effect on the metabolic rate was noted. Diiodotyrosine, however, caused a significant lowering of the metabolic rate within a few hours' time in thyroidectomized rats previously injected with thyroxine. Injections of potassium iodide containing an amount of iodine equivalent to that of the diiodotyrosine injection did not cause significant lowering of the metabolic rate.

For purposes of experiment eleven rats were used, approximately six months of age when the experiment was begun. Seven of these, four males and three females, were thyroidectomized. The remaining four were intact animals, one being a male, the other three females. Each rat during an experimental period was given a single subcutaneous injection of pure crystalline thyroxine (Squibb) in alkaline solution. The dosage in each case was 0.5 mgm. Single subcutaneous injections of diiodotyrosine (3,5-diiodotyrosine Eastman) or of potassium iodide containing an equivalent amount of iodine were also given; the standard dosage was 50 mgm. of diiodotyrosine or 42 mgm. of potassium iodide. Previous attempts at feeding thyroxine and diiodotyrosine with the diet had proved unsuccessful, since the food intake could not be properly controlled and the pure crystalline thyroxine is insoluble in the acid of the stomach.

The oxygen consumption of the animals under observation was recorded in a rat-metabolism apparatus of the type described by Schwabe and Griffith (9). The metabolic rate was not determined basally for several reasons: (1) When the rat is starved its activity is increased, so that use of a narcotic is often necessary, a factor which will lower the metabolic rate; (2) When the metabolic rate is to be recorded on three or four successive days, starvation becomes inapplicable; and (3) When the rat is allowed a full diet, its oxygen consumption is more uniform for purposes of comparison. A pre-

liminary period during which oxygen consumption was not recorded allowed the system to reach equilibrium and the animal to become accustomed to the apparatus. After this initial period two determinations were made in each case. During the entire experimental period the rats were maintained on a stock diet and tap water.

#### THYROIDECTOMIZED RATS

The first experimental step was to determine the period of activity of a single dose of thyroxin in the thyroidectomized animal. For this purpose two rats were given 0.5 mgm. injections of thyroxin, and the oxygen consumption was determined at intervals. The peak oxygen consumption was reached on the sixth or seventh day after injection of thyroxin. A gradual decline in the effect was noted on the eighth and ninth days. The results of these determinations are recorded in Table I.

The effect of diiodotyrosine or of potassium iodide at the peak oxygen consumption produced by a 0.5 mgm. injection of thyroxin was next determined. The metabolic rates of four animals thus treated were measured at the peak. Immediately after this measurement subcutaneous injections of 50 mgm. of diiodotyrosine were given to two animals. Two others received 42 mgm. of potassium iodide. Approximately four hours later the oxygen consumption of each animal was recorded again. As the figures in the table indicate, diiodotyrosine lowered the metabolic rate significantly, whereas potassium iodide containing an equivalent amount of iodine had no appreciable action.

The effect of diiodotyrosine or of potassium iodide on the peak oxygen consumption produced by a single thyroxin injection when administered sometime before the peak was investigated. One rat received 50 mgm. of diiodotyrosine four days after the thyroxin injection; another received the same dose on the third day. A second pair were similarly treated, with potassium iodide substituted for diiodotyrosine; 50 mgm. of potassium iodide was given on the fourth day and 42 mgm. on the third. There was little difference in the results, whether treatment was given on the third or the fourth day after thyroxin injection. As shown in the table, diiodotyrosine exerted far more effect on the peak oxygen consumption than did potassium iodide.

TABLE I

## EFFECT OF THYROXIN, DIIODOTYROSINE, AND POTASSIUM IODIDE ON THE OXYGEN CONSUMPTION OF THYROIDECTOMIZED AND INTACT RATS

The figures in this table represent averages of the results obtained by treatment of two or more animals.

| Treatment                                                         | Oxygen consumption in cc./sq. m./min. |              |               |                |                |
|-------------------------------------------------------------------|---------------------------------------|--------------|---------------|----------------|----------------|
|                                                                   | Base                                  | Peak         |               | 24 hours after | 48 hours after |
|                                                                   |                                       | Preinjection | Postinjection |                |                |
| Thyroidectomized Rats                                             |                                       |              |               |                |                |
| 0.5 mgm. thyroxin .....                                           | 78                                    | 87           | ..            | 90             | 83             |
| 0.5 mgm. thyroxin, 50 mgm. diiodotyrosine (6th day)               | 66                                    | 89           | 72            | 69             | 72             |
| 0.5 mgm. thyroxin, 42 mgm. potassium iodide (6th day)             | 63                                    | 76           | 72            | 71             | 60             |
| 0.5 mgm. thyroxin, 50 mgm. diiodotyrosine (3d or 4th day) .....   | 69                                    | ..           | 86            | 75             | 78             |
| 0.5 mgm. thyroxin, 42 mgm. potassium iodide (3d or 4th day) ..... | 81                                    | '..          | 100           | 90             | 90             |
| Intact Rats                                                       |                                       |              |               |                |                |
| 50 mgm. diiodotyrosine .....                                      |                                       | (70) *       | (74) *        |                |                |
| 0.5 mgm. thyroxin, 50 mgm. diiodotyrosine (6th day) ..            | 108                                   | 130          | 115           | 116            | 111            |

\* The figures enclosed in parentheses, though too low to represent the actual oxygen consumption of the intact animal, nevertheless are true comparative values.

## INTACT RATS

As a check on these results the action of diiodotyrosine on the normal and thyroxin-elevated metabolic rates of intact rats was noted. The oxygen consumption of two normal animals was recorded, 50 mgm. injections of diiodotyrosine were given, and the oxygen consumption was again recorded several hours later. As the figures in the table indicate, diiodotyrosine alone did not appreciably change the metabolic rate of the intact animal.

The depression of the metabolic rate by diiodotyrosine at the

peak oxygen consumption produced by a single injection of thyroxin was determined in the same manner as in the thyroidectomized animals. Two intact rats were given metabolism tests and injected with 0.5 mgm. of thyroxin. At the peak of the elevated oxygen consumption after this injection the metabolic rates were recorded, 50-mgm. injections of diiodotyrosine were given, and the oxygen consumption was determined again several hours later. As the table indicates, diiodotyrosine caused a significant lowering of the metabolic rate within a few hours, the same reaction shown by thyroidectomized animals given similar treatment.

#### DISCUSSION

This effect of diiodotyrosine as noted in our experiments, together with recent closely related studies of others, provides a partial explanation for the action of iodine in the treatment of hyperthyroidism. There is still a wide difference of opinion regarding the mechanism of action of iodine in treatment of Graves' disease. One school of thought is that action is directly on the thyroid gland itself. It was Marine's opinion (6) that a mechanical constriction of the blood vessels, resulting from packing of colloid in the follicles, prevents hormone release from the gland. This theory in a modified form is held by Means (7) and his coworkers (12) at Harvard. They are convinced that iodine has no effect on the circulating hormone, but acts only on the gland, possibly producing a blockade of the secreting cells. Others consider the evidence in favor of action solely on the gland as insufficient. The English worker Eason (3) is of this opinion. There is considerable possibility that iodine acts on the circulating hormone as well as on the gland.

If the assumption is made that iodine affects only the gland itself, then there is no theoretical basis for the use of Lugol's solution to prevent the postoperative thyroid crisis often encountered after surgical treatment of Graves' disease. This procedure, however, has frequently been successful.

Recent studies closely related to our own may help to explain this effect of Lugol's solution. Anderson and Evans (1), while studying the effect of the thyrotropic hormone on guinea pigs, found that iodine prevents the rise in oxygen consumption usually caused by thyrotropin, with little effect on the histological changes produced by that hormone. It is possible that this effect may be related to

our own findings, that is, diiodotyrosine lowers the elevated metabolic effect of a dose of thyroxin. Sometime later Morton, Chaikoff, Rainhardt, and Anderson (8), working with radioiodine, proved that both diiodotyrosine and thyroxin can be synthesized in the complete absence of thyroid tissue. Our own work has shown that diiodotyrosine causes a significant lowering of the elevated metabolic rate which follows thyroxin injection. These findings suggested that possibly diiodotyrosine is first formed, and that it is this compound which produces the metabolic effect heretofore attributed to iodine. Our experimental work dealt only with the metabolic effect of diiodotyrosine. There may be other effects which warrant further investigation; for example, a considerable rapid weight loss and an increased irritability were noted in animals receiving the diiodotyrosine treatment after thyroxin injection.

Our results have not been in complete agreement with those obtained by Siebert and Linton (11) in their comparative studies on the effects of diiodotyrosine and of potassium iodide on metabolism. There are several factors which may account for this difference. The rats used in our experiment probably show a species variation in reaction when compared with guinea pigs used by Siebert and Linton. They determined the metabolic rate basally; we found it more convenient not to do so. Finally, our results were arrived at from the effect of a single injection of the substance to be tested in each case; those of Siebert and Linton were obtained after a period of continued oral administration.

The studies discussed above may provide an experimental basis for the postoperative use of Lugol's solution to prevent thyroid crisis, which often results from surgical treatment of hyperthyroidism. It must be pointed out, however, that the mechanism of action of iodine in this case is not understood and that it will be difficult to determine until the mechanism of action of the thyroid hormone itself is known.

#### SUMMARY AND CONCLUSION

Within four hours diiodotyrosine causes a definite depression of the elevated metabolic rate produced by previous injection of thyroxin. An injection of potassium iodide containing an equivalent amount of iodine does not have this effect.

HENRY FORD HOSPITAL  
DETROIT, MICHIGAN

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## THE EFFECT OF HEPARINIZATION ON THE QUICK PROTHROMBIN TEST \*

CONRAD R. LAM

**A**S A result of attempts to inhibit thrombosis in surgical patients there has been widespread use of heparin and dicumarol, two substances which, rightly or wrongly, have been grouped together as "the anticoagulants" (4). No standardized dose of either drug exists, the rate of administration being determined by the effect of the former on the clotting time and by the change in prothrombin concentration brought about by the latter. As soon as dicumarol was available, it was suggested that combined therapy would be convenient, with heparin given intravenously for two or three days during the latent phase of the orally administered dicumarol. Obviously, it is desirable to know what if any effect heparinization has on the commonly used tests for prothrombin which depend on the clotting time of recalcified plasma. The authors of one communication (1) considered the matter briefly and, without citing evidence, stated simply: "Since heparin does not influence the prothrombin time, the effect of dicoumarin (dicumarol) can be determined by determining the prothrombin time even when heparin is given at the same time."

This statement is not self-evident in view of the fact that Howell and Holt (3) considered heparin to be essentially an antiprothrombin, and this theory has not been conclusively disproved. A recent reviewer (2) declared: "In summarizing the action of heparin on the blood coagulation mechanism the bulk of evidence points to an inhibitory action of heparin both on the first stage of coagulation and on thrombin to prevent the second stage; but it can exert its action only in the presence of the serum albumin fraction."

The purpose of the present investigation was to determine whether the amount of heparin present in the circulating blood of a heparinized subject would have an effect on the Quick prothrombin test (5).

\* From the Division of General Surgery, Henry Ford Hospital, Detroit, Michigan.

In this test oxalated plasma is treated with an excess of rabbit-brain thromboplastin and an optimal amount of calcium chloride. The clotting time of this mixture is presumed to indicate the prothrombin concentration, percentage figures being obtained from an empirically constructed curve. With fresh active thromboplastin solution the clotting time of normal plasma in the human is 12 to 15 seconds and in the dog from 7 to 10 seconds.

The following protocol shows one of six typical experiments. The animal was a female dog weighing 14 kilos.

- 1:37. Specimen of blood for clotting time and prothrombin test withdrawn, after which 2 cc. of heparin (Liquaemin, Roche) was injected.  
2:05. Second specimen of blood withdrawn.

|                         | Clotting time | Prothrombin time |
|-------------------------|---------------|------------------|
| Control blood .....     | 5 min.        | 10 sec.          |
| Heparinized blood ..... | $\infty$      | 10 sec.          |

Sufficient observations have been made to render it certain that the experiments on dogs may be duplicated on humans. For example, a patient, P. G., was receiving heparin by continuous drip on account of postoperative pulmonary infarction. His clotting time was elevated from 4 to 11 minutes. A prothrombin determination at this time showed a value of 85 per cent, a figure not infrequently obtained in normal individuals. A second patient, G. W., with severe pulmonary infarction, had a clotting time of 4 minutes and an initial prothrombin level of 30 per cent. He was heparinized, and a week later, when the clotting time was 15 minutes, the prothrombin was 35 per cent of normal.

The following results were obtained by using a single injection (2 cc.) of heparin on a person weighing 74 kilos.

|                            | Clotting time | Prothrombin time |
|----------------------------|---------------|------------------|
| Before heparin .....       | 8 min.        | 15 sec.          |
| After heparin (19 min.) .. | 20 min.       | 15 sec.          |

It is evident from these data that the concentration of heparin obtained by *in vivo* heparinization was not sufficient to affect the Quick prothrombin test. On the other hand, an excess of the drug *in vitro* may render the plasma incoagulable. This occurred once when a blood specimen was inadvertently drawn from the needle which was being used for the continuous intravenous administration of the heparin solution.

It is suggested that heparin might better be called an antithromboplastic substance than an antiprothrombin, since no prothrombin deficiency could be detected in the heparinized blood, and since clotting occurred quite promptly when thromboplastin was added.

HENRY FORD HOSPITAL  
DETROIT, MICHIGAN

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## **SOCIOLOGY**



## DISPERSION VERSUS SEGREGATION

### APROPOS OF A SOLUTION OF RACE PROBLEMS

AMOS H. HAWLEY

**R**ECENT events in race relations are clearly indicative of serious stresses in our social structure, which may be expected to continue developing as the Negroes become more articulate and more competent to share in the responsibilities and privileges of society. There seems to be general agreement that a solution, or at least a policy promising an early solution, of interracial difficulties is urgently needed. The very complexity of the problem, however, is sufficient, in view of existing knowledge, to deter any but the foolhardy from voicing suggestions. Nevertheless, the author proposes to offer a suggestion. But the present paper does not expound a plan; rather, it offers a direction of thought which, if explored further, may lead to a solution.

Basic in all instances of race conflict, and perhaps of majority-minority group conflict in general, is the fact of intergroup competition. The specific criteria by which the dominant and the subordinate groups are distinguished are themselves of incidental significance. What is important is that two such populations represent rival claimants to local resources or alternative labor supplies. The rôle of the contests between colonial and native peoples and of labor conflicts in shaping our patterns of race relations is too well known to require review here.

The particular status of the population at a disadvantage takes form as members of the dominant group seek to narrow the sphere of competition by excluding from free participation in common activities all individuals who conform to a certain definition. Conceivably, discriminatory action may be directed toward any definable segment of the population. Usually, of course, it centers upon a recognized minority which happens to be conspicuous as a result of its physical peculiarities, its segregated existence, its unique historic past, or all taken together. Exclusion finds justification in the majority group on the score of an alleged inferiority of ability and



general social worth inherent in members of the lesser group. Hence the position of the latter becomes circumscribed by numerous prejudicial practices and fictions aimed at isolating it from all claims to equality in community life.

To be sure, a group may contribute to its own segregation. Voluntary or "accidental" segregation frequently occurs. Cultural enclaves are formed by immigrants because of their inability to effect an immediate transition to the mode of life in the new area, and by religious sectarians who wish to foster a peculiar pattern of living. On the other hand, a group confronted with discrimination is awakened to self-consciousness and strives defensively to create a society of its own. The compensatory reaction often entails a more complete withdrawal into a restricted area and type of life than conditions warrant. In all such instances the group assumes the risk of incurring discrimination or increased discrimination.

Systematic discrimination against a racial or minority group is visible in segregation, which may appear in manifold forms. Residential restrictions, confinement to certain occupations, exclusion from use of public facilities, denial of the franchise and of access to courts of law, charges of moral and intellectual ineptitude, these and other manifestations of segregation operate in various combinations. The subordinate status of the group may be read from the modes of segregation to which it is subjected. There is little question but that segregation is the root of the problem viewed from the standpoint of the minority population.

Now, though an imposed segregation is expressed in many ways, it seems that the most fundamental form is spatial or residential. The function of all restrictions of this order is obviously to protect a competitive advantage for the dominant group. Spatial segregation, however, contributes to this end more directly and effectively than does any other type of circumscription. It is the fullest practicable attainment of exclusion and isolation. The physical separation of the opposed groups is in itself a barrier to participation by one in the affairs of the other. But it also has the effect of throwing into sharp focus the differences between the groups; in fact, it accentuates those differences through heightening the visibility of the minority population. In exaggerating the illusion of homogeneity and, at the same time, obscuring the reality of individual variation spatial segregation provides support for prevailing stereotypes.

Prejudicial beliefs are further reinforced by the aspect of concreteness which is lent thereby to social distance. In short, spatial segregation keeps the interracial issue in the foreground of attention, clearly defines the accepted interrelations, and simplifies the problem of control. Separation in space is probably an indispensable condition of subordinate status applied to a group as a whole. A fair generalization from history would seem to be that no minority group — racial, ethnic, religious, or political — may long exist without some degree of physical isolation.

Given the hypothesis of a necessary dependence of subordinate group status upon spatial segregation, it follows that a breakdown of the isolation and a scattering of the group is the essential first step in obviating the position of inferiority. Redistribution of the members of the subjugated group to approximate the same pattern of territorial spread characterizing the dominant population would, by this reasoning, reduce the competitive threat felt in any one area or sector of the economy, differentiate the minority so fully as to prevent its appearing as a homogeneous mass, and eliminate the identity of the group. The group would thus be absorbed in the general population. These are inferences which must be examined more carefully.

Competition is a function of the ratio of resources to population. Its intensity rises and falls as the relative value of the denominator in the fraction increases or decreases. But where the population is subdivided into groups competition tends to shift from an interindividual to an intergroup basis. When this occurs the fundamental competitive issue is altered; to the problem of how much each individual competitor will be able to obtain is added the problem of how many individuals from each group will have opportunity to enter into the competition. An unknown factor in this connection concerns the limits of tolerance in one group for competitors of a second group: At what point in the changing numerical balance, that is, does competition shift from an interindividual to an intergroup basis? Though this question is not answerable at present, it is nevertheless clear that, when Group A comprises the overwhelming majority of the individuals involved in competition, the relationship tends to remain on an interindividual basis. But as Group B increases proportionally to Group A, competition may be expected to assume more of an intergroup aspect.

It is common knowledge, for example, that representatives of alien groups living among a native population experience few, if any, restrictions so long as their numbers are small. The Jews remaining in Spain after the great expulsion in the sixteenth century enjoyed the same privileges that were accorded the gentile population. Likewise, Jews born and raised in small American towns where their numbers are slight are often unfamiliar with practices of anti-Semitism. They are accepted and frequently are so assimilated to the life of the community as to be scarcely aware of themselves as in any way different from their fellow citizens.<sup>1</sup> Essentially similar experiences have been had by early migrants from Europe, by Orientals in the United States, and by Negroes when they are thinly scattered among the white population. The small numbers of Negroes living in Northern states had, prior to the Negro migrations of 1916-19, an enviable freedom of activity and opportunity by contrast with their coracialists in the South. In Iowa, to cite but one instance, in the years during World War I Negro labor was solicited, paid the same wages as white labor, admitted to skilled employment in all industries, and subjected to no discrimination.<sup>2</sup> The Negro population of Iowa at the time was less than one per cent of the total.

When, however, the size of an alien or a subordinate group begins to increase relative to the native or dominant group and to loom progressively larger as a competitive force, tensions develop, restrictions accumulate, and the minority is more and more suppressed. Traditionally minority peoples are well aware of this. Descendants of early Jewish settlers in the United States looked with dismay upon the large influx of Russian and Polish Jews in the latter part of the nineteenth century. They made an unsuccessful attempt to colonize the newcomers in the less densely settled agricultural areas of the country.<sup>3</sup> Similarly, Northern Negroes feared the northward migrations of Southern Negroes. Events confirmed their appre-

<sup>1</sup> Drachler, Julius, "Prejudice as a Social Phenomenon," *Jewish Experiences in America*, ed. by Bruno Laaker (New York, 1930), pp. 142-144.

<sup>2</sup> United States Department of Labor, *Negro Migrations in 1916-17* (Washington, D.C., 1919), p. 109. According to C. S. Johnson, *The Negro in American Civilization* (New York, 1928), p. 148, Negro lynchings are most frequent in counties where the proportion of Negroes is highest, in other words, "where competition is more severe."

<sup>3</sup> Wirth, Louis, *The Ghetto* (Chicago, 1928), p. 148.

hensions. Wherever in the North migration brought an appreciable increase in the Negro population, the behavior of the white population underwent a marked change. Northern whites became aware of a race problem. The free access to stores, schools, churches, and employment opportunities which the old Negro populations in Chicago, Dayton, Detroit, Philadelphia, and other cities had enjoyed was gradually withdrawn.<sup>4</sup> Differentiation and segregation became more rigorous and were applied alike to the old residents and the new arrivals.

It is of interest to note, parenthetically, that the response of Southern whites to the exodus of Negroes was an attempt to arrest the movement. Finding that licensing of labor recruiters at exorbitant fees, interference with the mail, violent attacks upon migrating Negroes, and other negative measures failed, the South resorted to more persuasive and positive steps. As a result, some improvements were made in Negro-white relations. Wage differentials were reduced, short-weighting and cheating in stores and commissaries were stopped in many localities, working conditions generally were improved, inequalities in education were partially removed, and a number of minor changes were brought about.

The phenomenon of increasing strain with increasing numbers has been observed in other connections. The Chinese, who at first were welcomed to the Pacific Coast as "ideal" citizens and workmen, were abruptly made the butt of hostilities when, in the period 1869-85, as the transcontinental railroads were completed, they were dumped upon the labor markets of western cities. At a later date Japanese immigrants passed through the same cycle of welcome and opposition as the mounting competition of their growing numbers began to be felt. An Asiatic Exclusion League, formed to press for legal exclusion of the Oriental immigrant, was constituted by 238 member associations, 202 of which were labor organizations. The series of events which led to Oriental debarment was, however, but a phase in a larger development aimed at the immigration of aliens in general. Southeastern Europeans, finding no free land available, crowded into the cities of the East and the Middle West in search

<sup>4</sup> Chicago Race Commission, *The Negro in Chicago* (Chicago, 1922), p. 278; William Pickens, "Negro Migrations," *Forum*, 72 (1924): 603; Emmett J. Scott, *Negro Migrations during the War* (New York, 1920), p. 136; Detroit Bureau of Governmental Research, *The Negro in Detroit* (Detroit, 1926), Part II, pp. 19-20.

of industrial employment. Their competition gave rise to the hue and cry "the new immigration." Finally, the traditional policy of the United States encouraging immigration was reversed in the quota enactments. In the East, as in the West, organized labor assumed the leadership in securing immigration restriction.

Related to the influence of numbers through their bearing upon competition in affecting subordinate-group status is the quality of homogeneity in the group concerned. An important feature of discriminatory and segregative practices is their categorical character; they imply that the population upon which they are directed is an undifferentiated mass, each individual being just as inferior as the next. Despite the manifest error in such an implication, it contains an element of truth. A spatially segregated group not only appears to be but is actually homogeneous in certain general respects as, for example, its qualifications for employment in the institutions controlled by the dominant group. Segregation, whether voluntary or involuntary, is a restriction of opportunity; it hampers the flow of knowledge and experience and thus impedes diversification of interests and occupations. Migrants settling in a new and strange community are for the most part fitted for only the least specialized functions. And to the extent that they establish a segregated existence in the new community the alien individuals tend to retain their uniformity. Spatial segregation, therefore, operates in two ways to preserve a minority status. In that it causes the group's peculiarities to stand out in clear contrast to the traits of the majority, it emphasizes the uniformity within the group. Thus the group is exposed to categorical definitions of one kind and another. But spatial segregation also imposes a certain limitation of opportunity which interferes with the differentiation of individuals composing the group.

The redistribution of a segregated population may be expected to dissolve the attribute of homogeneity, both apparent and actual. The departure from the norm evident in the peculiar traits possessed by members of the minority group loses its massive character as the individuals separate and scatter over a wide area. Individual variants are expected and tolerated in local situations. Moreover, since the individual who is removed from his group cannot easily be viewed against the background of his racial or ethnic fellows, he tends to be regarded less as a representative of a type and more as an individual. Furthermore, a group whose members become

widely distributed sooner or later loses its ability to act in concert and hence its identity as a group. It may possibly be reconstructed as a statistical class, but it cannot be regarded as a group in the sociological sense.

The histories of various European nationality groups settling in the United States are illustrative. So long as they remained compact units they kept their national traits and group structures. Under such circumstances they were also subject to attacks and subordination by the native population. On various occasions the Irish, Greeks, Italians, Poles, and many others have known the meaning of minority status. The progeny of immigrants, however, drift away from the foreign settlement and merge with the general population. Eventually the group itself disappears unless it is replenished by fresh immigration.

Colored populations, of course, have greater difficulty in losing themselves in the white group. Even so, the principle of small numbers seems to operate in their case as in the others, as has already been indicated. Anyone who has observed the behavior of experienced Negroes in formal public gatherings in which whites are numerically predominant has noted that, instead of congregating, they disperse and keep apart from one another. Color is not so foreboding in an individual as in a mass of individuals.<sup>5</sup> It is not unlikely that the redistribution of Japanese-Americans in rural areas, villages, and cities throughout the nation, being carried on at present by the War Relocation Authority, will end that problem and culminate in their final acceptance on an equal footing in American society.

The actual differentiation of the group is of greater importance. Migration, we know, is an educative experience; it opens new vistas and provides a basis for comparison and criticism of the familiar. It expands the scope of one's knowledge and action and thus stimulates the development of latent potentialities. Relocation in a new geographical and social context requires, in fact, readaptation of the migrant's behavior. Old habits must be modified and novel patterns of behavior must be acquired in order to deal successfully with the new habitat. It is not surprising, therefore, that migration almost invariably involves a change of type of occupation.<sup>6</sup> The extensive

<sup>5</sup> See Herman Feldman, *Racial Factors in American Industry* (New York, 1931), pp. 271-272.

<sup>6</sup> Social Science Research Council, Bulletin 42, Rupert Vance, *Research*

occupational diversification of the Negro population occurred with, if not as a result of, its large-scale movement from the South to the North and from rural to urban areas in the South. But the still considerable concentration of Negroes in a few types of employment is evidence of the continuing segregation of the group, in the Southern region primarily, though also in restricted zones in cities.<sup>7</sup>

The fragmentary materials which have been assembled in this discussion would seem to support the hypothesis as originally set forth: Redistribution of a minority group in the same territorial pattern as that of the majority group results in a dissipation of subordinate status and an assimilation of the subjugated group into the social structure. At least, the evidence is sufficient to recommend a further and more systematic testing of the proposition. Two basic corollary problems have been indicated, and these may be suggested as the immediate points of departure for research.

First, what, precisely, is the numerical ratio in the sizes of two juxtaposed groups at which intergroup competition emerges, what are the secondary variables, and how do the secondary factors operate? Fluctuations in employment opportunities and the value of money undoubtedly are important in shifting the "critical ratio" from time to time. The bearing that various historical events have on the cleavages that develop and how these affect the saturation point will need special attention.

Secondly, how fully and how rapidly is differentiation achieved by the scattering of a comparatively homogeneous group? It would be well, if possible, for this process to be investigated with respect to individual interests, local loyalties, and institutional participation, as well as in regard to occupations.

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*Memorandum on Population Redistribution in the United States* (New York, 1938), p. 110; Albert H. Hobbs, *Differentials in Internal Migration* (Philadelphia, 1942), pp. 72-87.

<sup>7</sup> Of the 2,790,000 Negroes in the North in 1940, 1,815,963, or 65 per cent, resided in twenty-three cities. Northern cities of 100,000 or more population contained 70 per cent of the Negro population.

## AN INQUIRY INTO THE NATURE OF THE AMERICAN WAY OF LIFE

ROY H. HOLMES

AMERICAN sociologists would seem to have no more appropriate task in these tragic days of world-wide destruction than that of examining the American way of life or culture in the attempt to ascertain whether one may reasonably suppose that it is in considerable part responsible for the calamities now being experienced by humanity in general. Though sociologists, as such, are no more competent than other scientists to ascertain what values men should live by, they should be able to indicate causal relationships in society and to determine which values are in their nature constructive or life-giving and which, on the other hand, are destructive.

The purpose of the present paper is to contribute something toward an examination of the American way of life. Specifically, it is my desire to determine the approximate location of this way of life or culture within a frame of reference arranged in terms of individual freedom. By "freedom" is meant what C. H. Cooley meant — the opportunity for right or good development. The individual is born with certain potentialities. In the ideally free society each person would be nurtured under such conditions that his inherent capacities would be brought to something like complete development and expression, within socially approved channels. Such a society may rightly be called a democracy, which is here defined as a social system in which the dignity of the individual as a person is respected above all other values. A culture whose mores insist that each person should be given such respect, including opportunity for such complete development and expression, may be called a democratic culture. Democracy, thus defined, would make the very most that could be made of human life, within the limits of the physical resources and the scientific knowledge of a given time and place.

Let us place, then, at one side of our frame of reference this



concept of democracy. At the opposite side we shall place the concept of the completely dictatorial society, in which respect for human dignity is entirely lacking. On the one hand, we have the concept of complete freedom; on the other, that of complete slavery. Our task is to locate within this frame the concept of the American way of life.

The thesis which I am attempting to support is that the American way of life is considerably closer to the dictatorial side of our frame of reference than to the democratic—that the so-called “freedom” generally acclaimed is actually in its nature more largely a condition of slavery than one of true freedom.



The American culture is one of individualism. Most Americans, when they say that we are fighting to maintain our way of life, have in mind the traditional right of each person to strive for material gain with a minimum of external restraint, along with the right to resist such restraints as governmental or other agencies seek to impose. The mores of this culture reach each person through the expectations of his associates. In general, normally ambitious young men are given to understand through the influence of most of those whose opinions they value that they should seek to advance themselves in a material way without regard for the general welfare, and possibly even deliberately at the expense of fellow Americans. However much may have been made in their childhood days of the desirability of respect for the personality of others, as embodied in the Golden Rule, the insistence of the mores when they become men is that they then should put away such ideals of childhood and begin living the American way. Those who choose to do otherwise may be either praised or ridiculed as nonconformists. To advocate, however, the organization of the whole life of the nation in accordance with democratic or Christian principles, including respect for the personality of each person, is generally condemned as un-American. Americanism is individualism, a more thoroughgoing ruthless individualism than that characterizing other nations which share the traditions of western civilization.

It is to be assumed that all of this is common knowledge to sociologists. The points to be kept especially in mind throughout the ensuing analysis are three: (1) Americans behave the way they do because of their culture, and not, as is popularly said, because of human nature or because of some special American variety of human nature. Their behavior is because of culture; and cultures, as we know, are subject to change. (2) There is an interrelationship among all the various parts of American life. In the words of Lewis Mumford, "Every element in life forms part of a cultural mesh." (3) The individualistic culture, in its strong emphasis upon the rightness of personal disregard for the general welfare, is essentially a destructive culture. And, owing to the interrelatedness of all elements of this culture, one finds widespread destructiveness affecting American life in its various aspects, which is in the main traceable to one basic motive, the overwhelming desire of the individual, because of the mores, for personal material advantage.

Poverty in the midst of plenty is one of the more obvious illustrations of the destructiveness of the individualistic culture. Viewed either in its individual or in its social aspects, the human loss arising from poverty is clearly evident. This poverty is due in large part to prolonged periods of unemployment and to low wages of those who are employed. Unemployment and low wages are in turn largely the result of the monopolistic organization of private industry, which in its turn has developed because of the individualistic mores of the American people. The *material* loss alone because of unemployment is tremendous, for it is estimated that that of the Great Depression cost the nation 200 billion dollars.

The destructiveness of the individualistic culture is to be seen also in the great waste incurred through conflict of management and labor. Management and labor each strive for material gain at the expense of the other, and with little evident regard for the general welfare.

Crime for financial gain rests very largely on our individualistic mores. This type of crime is an extremely important factor in American life, ranging all the way down from the large-scale depredations of violators of Federal antimonopoly laws, through the individualistic manipulations of so-called public servants who solicit and accept bribes and the activities of men who hold up

banks and filling stations, to the antisocial scheming of perfectly reputable citizens who are guilty of petty infractions of rationing regulations. The line separating legitimate business practices from those that are illegal is thin, often uncertain, and largely unrealistic. The law-abiding businessman and the criminal are both actuated by the same motive, the desire to benefit in a material way without regard for the public welfare. Because they are both marching in the same general direction it is often difficult to tell them apart. The mores are much more influential on American conduct than is respect for law. In other words, the prevailing mores do not demand that laws, as such, be respected. We make laws with our heads whereas we follow the mores with our hearts. Where there is conflict between heads and hearts, between reasoned conclusions and feelings which are expressive of deep-lying values, feelings may be expected to win.

Political-party conflict is largely destructive, for party interests and group interests within parties take precedence over the general welfare. It is but playing the political game according to the mores if, for example, those who think they might personally gain by preventing soldiers from voting should attempt to do just that. In individualistic America a statesman, or one who puts chief emphasis upon the welfare of the country as a whole, is bound to be a nonconformist. The typical American individualist simply cannot understand such a person.

Racial and religious discrimination fits well into the picture of the mores of the culture. Though factors other than individualism may be in part responsible for this destructive manifestation of the American way of life, it seems clearly evident that it cannot be significantly reduced as long as American values derived from the traditional culture remain essentially unchanged. Individualistic competition for economic success readily assumes extremely harsh forms when members of one race only are involved. When an ambitious competitor sees a possible advantage to himself through capitalizing upon existing prejudices against members of minority groups, it is but to be expected that he will grasp at this advantage, while at the same time doing what he can to deepen the prejudices already operating.

The rôle of women in America is obviously determined largely by the culture of individualism. Traditionally, the good marriage

from the woman's point of view is one in which there is evident assurance of economic security. Women who marry well are free to assume as much or as little personal responsibility for the welfare of those outside the immediate family as their backgrounds incline them to do. Very largely the existence of these women is parasitic. Those whose marriages are less favorable from the standpoint of economic security engage in a vast amount of very real drudgery, work that is not peculiarly suited to the individual natures of those who are engaged in it. America experiences a tremendous waste of human resources through this combination of parasitism and drudgery of her women, which waste is directly attributable to the nature of our culture.

Then there is the general social neglect of the children, which inevitably results in the inadequate preparation of many of them for efficient wholesome living in their adult years. Juvenile delinquency in the technical sense is but a relatively small part of the total unfavorable situation as regards the young. They are largely neglected because the mores do not demand major concern for the general welfare, including that of the children. It is merely assumed for the most part that child care is almost the sole responsibility of the parents, who, under urban conditions, are for various reasons incapable of bearing that responsibility in any adequate way.

This list of the manifestations of destructiveness to be observed within the nation might be considerably extended. The important things are to realize that all these separate manifestations are products of the same basic spirit, which is generally known as the American way of life, and to realize also that, when they are regarded as problems, there is no real solution for any one of them which would not involve a revolutionary change in this way of life.

National isolationism, the refusal of the nation to be deeply concerned about the welfare of the world as a whole, springs from the same common source. The way of life or culture that compels most Americans to disregard the general welfare of fellow Americans compels at the same time those who determine America's foreign policy to disregard the general welfare of the world. Our present war is a product of such irresponsibility. There is good reason to hold that it is due as much to this individualistic American way of life as it is to the destructive impulses within any other nation. Hope for an enduring peace must be premised on a revolutionary

change in our mores in the direction of democratic or Christian values which will affect every phase of our domestic life as well as our relationship to all other nations.

The conflict between heads and hearts, or between opinions and attitudes, referred to above in what was said about law and crime, may very profitably be observed in the sayings and doings of national leaders in the fields of industry and finance. The public statements of these men, which it is assumed are being made in all sincerity, very largely voice the determination to cooperate wholeheartedly with the leaders of all other groups within the nation to bring into being a much better day for all Americans. Much is said about the need for abolition of private monopoly, about the possibility of an economy of plenty, and about the realization that no one group can long be prosperous unless other groups are prosperous. In their statements the men are really expressing their honest opinions, it may quite safely be assumed. They cannot, however, implement their democratic resolutions without turning their backs upon the teachings of their fathers and the habits of a lifetime. They say that for the good of the nation other sorts of people should be prosperous. The loyalty of these leaders to the traditional American culture, however, if it remains unaltered, will drive them in the future, as it has in the past, to attempt to prosper at the expense of the prosperity of other groups and classes. Specifically, to illustrate published opinion, the president of the United States Chamber of Commerce remarks in a magazine article: "No, I am not for going back to 'the good old days.' Moreover, I am not convinced that we would if we could. For whom were they good? I doubt if they were good for anybody. Business has paid the penalty for its complacency." At the same time there are attitudes very definitely in conflict with such published opinions, for we find a large number of important corporations spending many millions of dollars in the attempt to preserve the *status quo* through advertising campaigns dedicated to the proposition that America's traditional values should remain unchanged.

A continuance of our individualistic culture will lead inevitably to a dictatorial state. According to the traditional American way of life, each person tends to exercise dictatorial control over as much of life as he is able to dominate. The values of our culture are of the might-makes-right sort. With increasing tensions disciplined order

can be achieved only through completely centralized military control exercised by the state.

The only alternative, democratic discipline, can be developed solely as a result of a moral revolution, with the mores being transformed so that they come to demand service to others instead of acquisition from or exploitation of others. With such mores the human-nature urge for prestige will force the individual to strive as wholeheartedly for the general welfare as under our present culture he is driven to neglect it for the sake of his own material gain.

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